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AN AUTOMATIC TIT-TAT-TO MACHINE.*

FRANK T. FREELAND,
University of Pennsylvania, Class of 1879.

The problem of designing a machine which would play one of the games of skill, has been attempted many times. Several automata have been constructed which would play the game of chess; but it was always found upon investigation, that their motions were controlled by a hidden confederate. The infinite number of variations in chess renders the construction of a true chess automaton impossible. Mr. Babbage, the inventor of the difference engine, in his ninth Bridgewater treatise, refers to the possibility of constructing an automaton which would play a much simpler game, that of tit-tat-to. A gentleman of this city has invented and made some drawings of such an automaton, working upon the principle of a movable Jacquard loom card. The machine herein described works upon an entirely different principle, that of a *mechanical table*, which contains all the possible variations of the game.

---

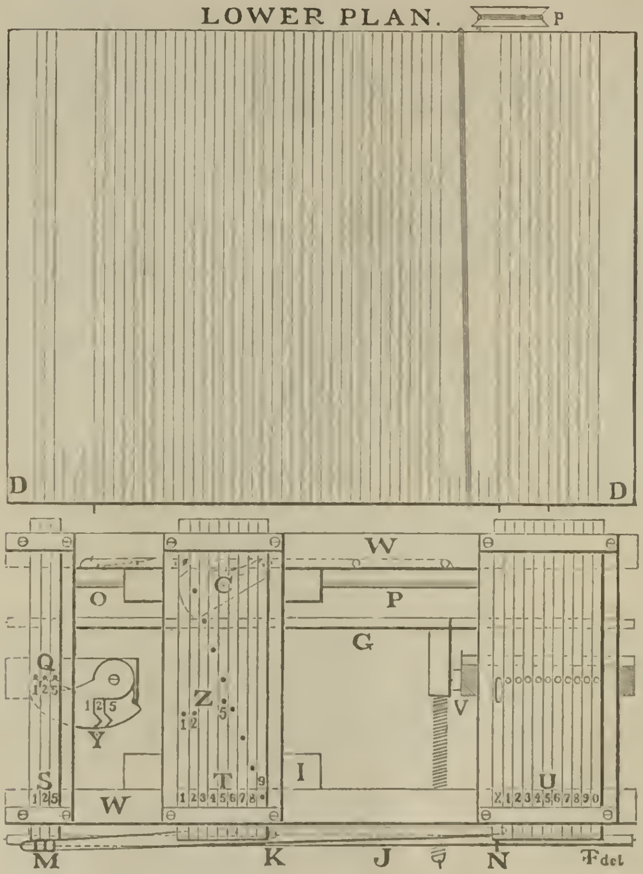
* UNIVERSITY OF PENNA., PHILA., *November 9th*, 1878.

Dear Sir:—I hand you herewith, description and drawings of the automatic Tit-Tat-To Player, exhibited at your last meeting. The invention displays so much mechanical genius that it cannot but prove of interest, and perhaps of service, to all mechanicians.

Respectfully,

WM. D. MARKS.

To J. B. KNIGHT, ESQ., Secretary Franklin Institute.



The game of tit-tat-to is played by two persons. A double cross is drawn upon a sheet of paper. One of the players chooses a cross (×) for his mark, and writes it in one of the spaces 1–9. The other player chooses a zero (0), and writes it in one of the remaining spaces, and so on alternately. The game is won by the player who first succeeds in getting three of his marks in a row. If the spaces are all filled before either player gets a row, the game is drawn.

1	2	3
4	5	6
7	8	9

The following is an exhaustive analysis of the game of tit-tat-to, for a machine to play the game, under the conditions that the machine shall always play the best move; and that when the opponent, during the first three moves of each game, wishes to play one of two or four symmetrical moves, he shall take the one having the lowest number.

THE OPPONENT BEGINS.

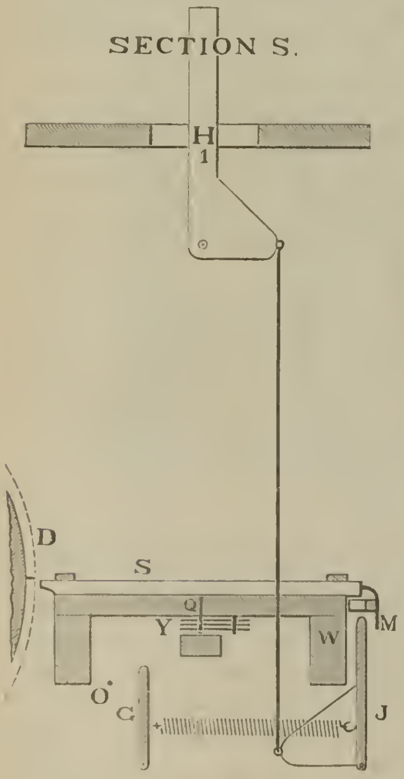
[These games will be found upon the *Surface of the Cylinder*, lines 1—74 inclusive.]

THE MACHINE BEGINS.

0	×	0	×	0	×	0	×	0	Res.
1	2	5	9	7	4	3			0
					367	4			0
			34678	9					0
	3	4	7	5	9	6			0
					268	9			0
			25689	7					0
	5	9	2	8	7	3	4	6	0
							6	4	—
					345	7			0
			3	7	4	8			0
					268	4			0
			6	4	7	3	2	8	—
							8	2	0
					238	7			0
	6	7	4	5	3	9			0
					289	3			0
			23589	4					0
	9	3	2	7	4	5			0
					568	4			0
			45678	2					0
2	1	5	8	7	3	6	4	9	—
					469	3			0
			34679	8					0
	4	1	3	5	9	8			0
					678	9			0
			56789	3					0
	5	1	3	7	4	6	8	9	—
							9	8	—
					689	4			0
			46789	3					0
	7	1	3	5	9	8			0
					468	9			0
			45689	3					0
	8	1	3	9	5	7	4	6	—
							6	4	0
					467	5			0
			45679	3					0
5	1	2	8	7	3	6	4	9	—
							9	4	0
					469	3			0
			34679	8					0
	2	1	9	4	6	7			0
					345	6			0
			34678	9					0

The method of transforming this symbolic table into a mechanical one, will be obtained by a comparison of it with the *Surface of the Cylinder*, beginning at line 75. There are one hundred and fifty lines upon the cylinder. The omitted ones may be obtained from the latter part of the above table. Our 1st, 2d, 3d and 4th moves in any game are set down in the columns T I, II, III and IV. Each column contains nine vertical lines. The figure 1 is represented by a pin upon the first line; 2, by a pin upon the second line, etc. The machine's answering moves are set down in the column U, upon the same horizontal line as ours. Whenever its move gives it three in a row, another pin is put upon the line U0. The row of pins Ux affords a hold to a catch. When the machine begins, its first move is set down in the column S.

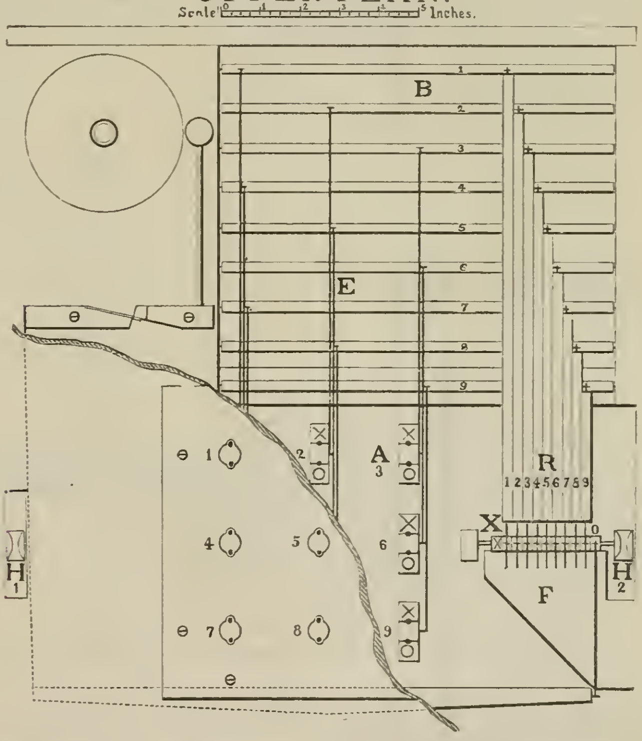
Description.—In the *Lower Plan*, the cylinder *D* is represented, its surface being prepared as described above. The cord, weight and pulley *p*, give it a tendency to turn toward us. In front of it are the two cross-beams or ways *W W*. On them the carriage *I* runs. The cord *P*, running over a pulley to a weight, gives the carriage a tendency to move to the right. The carriage has a catch *C*, which engages with four pins set in a groove in one of the ways. Whenever the catch *C* is pushed, the carriage *I* moves a space to the right, equal to one column of the table. The wire *O* is to draw it back to its first position. On the carriage are nine sliders, *T* 1–9. When they move forward, they engage with the pins upon the cylinder. *T* 1, 2 and 5 have the pins *Z* 1, 2 and 5 in them, which project below the carriage.



A platform is secured to the ways at the left. On it are the sliders *S* 1, 2 and 5, having in them the pins *Q* 1, 2 and 5, which project below the platform. Supported on a bracket, under the platform, are the flat, horizontal cams *Y* 1, 2 and 5. When the carriage is in its first position, the pins *Q* 1, 2, 5 and *Z* 1, 2, 5 engage with these cams. They are of such a shape, that when the slider *T* 1, 2 or 5 moves backward, the pin *Z* 1, 2 or 5 rubs over the pointed end of the cam *Y* 1, 2 or 5, and so pushes *S* 1, 2 or 5 forward.

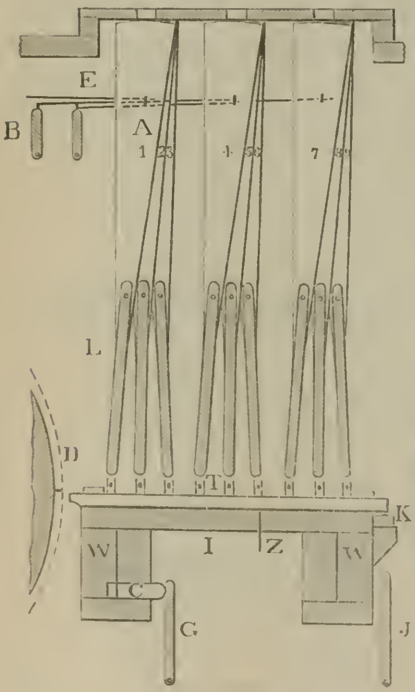
At the right is secured to the ways a platform, on which are the sliders Ux, 1–9, 0. The slider *Ux*, by engaging with the row of pins *Ux*, locks the cylinder. *U* 1–9 discover the answering move. *U*0 determines the striking of the bell. These sliders are set at a higher level than the others, so that when they move forward, they impinge upon the pins, instead of going under them. *K* is a horizontal lever, pivoted at its centre. *S* 1, 2, 5 and *Ux* have in their ends bent wires, *M* and *N*, so that when *S* 1, 2 or 5 moves forward, *K* pulls *Ux* backward. *J* is a vertical leaf, pivoted at its lower

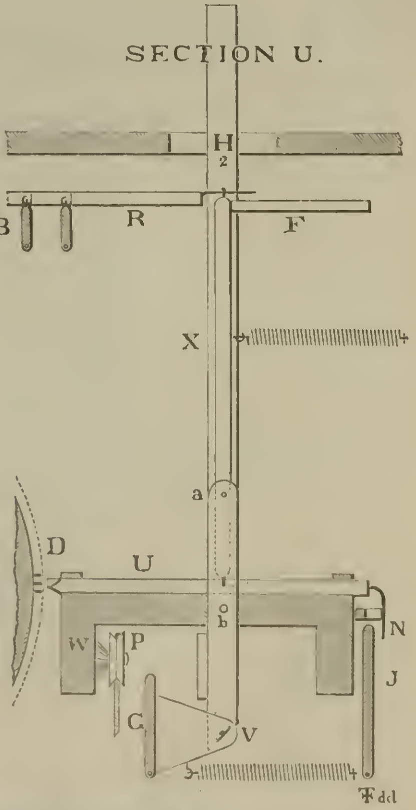
UPPER PLAN.



corners, and connected by a double bell-crank with the lever *H* 1, as shown in *Section S*. When *H* 1 is pushed forward, *J* draws out the catch *Ux* and the sliders *S* 1, 2 and 5. *G* is a vertical leaf, pivoted at its lower corners. When it moves toward the cylinder, it releases the carriage by striking the catch *C*. *G* has secured to it an arm with a pin in it, as shown at *V*, *Section U*.

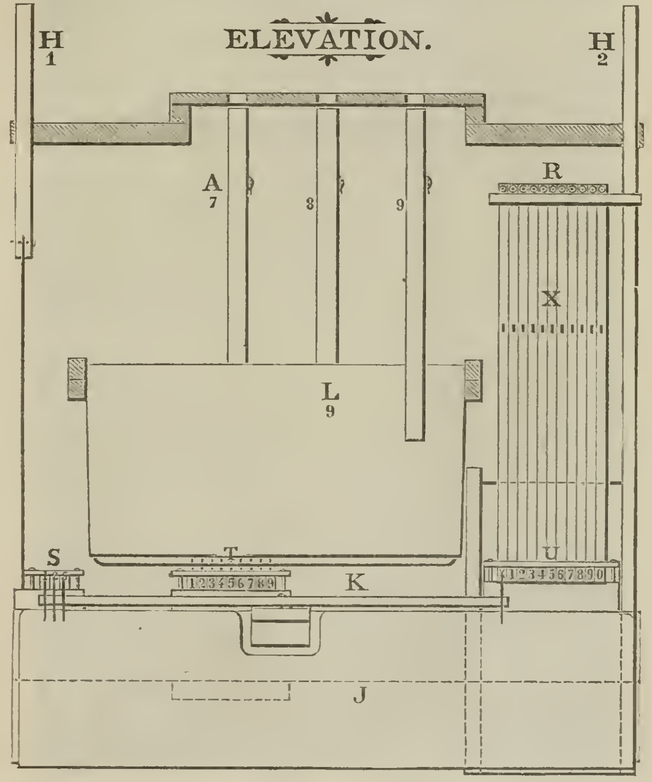
SECTION T.





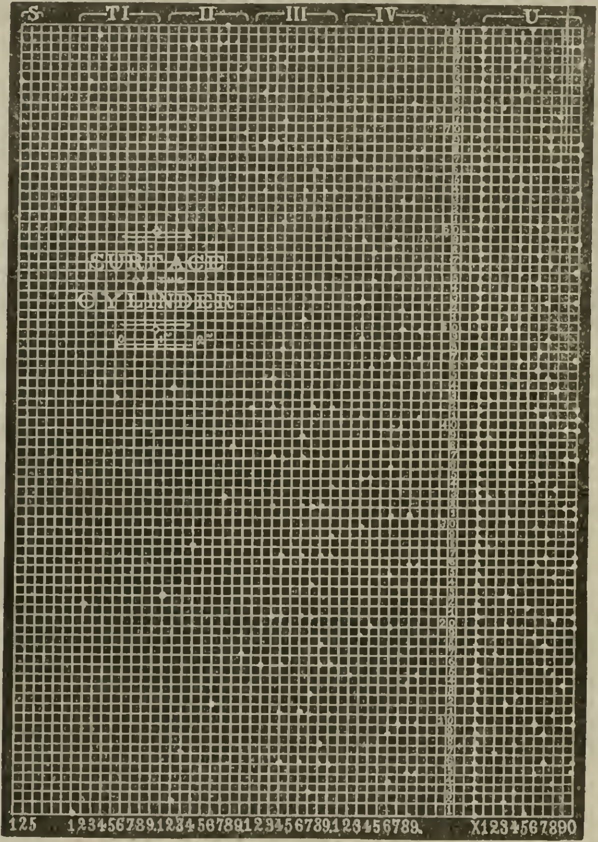
In the *Upper Plan*, is shown a portion of the board. It has nine openings in it. Under them move the arcs *A* 1–9. There is a cross (×) on one end of each, and a zero (0) on the other. These arcs are secured to the vertical leaves *L* 1–9, which are pivoted at their upper corners. By long wire teeth they gear into the sliders *T* 1–9 in such a way, that they do not get out of gear when the carriage moves to the right or left. See the *Elevation* and *Section T*.

In *Section U*, the levers *H* 2 and *ab* are represented. They are pivoted on each side of the platform at *b*, and firmly united by a cross-piece under the platform. On the lower end of *ab* is fastened an inclined plate *V*. When the lever *H* 2 moves backward, the plate *V* lifts the arm of *G* by the pin on it, and so releases the carriage. From *ab* to *H* 2 at the point *a* runs a stout wire. On it are strung the vertical levers *Xx*, 1–9, 0. Their upper ends are held back against the plate *F*, which serves as a fulcrum, by the springs as shown. Their lower ends are geared into the sliders *Ux*, 1–9, 0. When *H* 2, containing the point *a*, moves forward, the levers *Xx*, 1–9, 0 move forward, their upper ends being their fulcrums, pushing the sliders *Ux*, 1–9, 0 forward. If one of these impinges on a pin, it stops, and becomes the fulcrum of the *X* belonging to it. Then the upper end of that *X* goes forward, elongating the spring. The slider *Ux* has a slot at its point of gearing, so that when it is carried forward it is left there. When the upper ends of



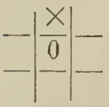
T.del.

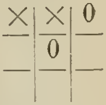
X 1–9 move forward, they strike the rods R 1–9, which are hooked to the vertical leaves B 1–9, pivoted at their lower corners. These are connected by the wire links E 1–9 with the arcs. When the upper end of $X0$ goes forward, it causes a bell to strike.

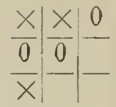


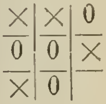
Operation.—The machine is wound up by setting all the arcs at their middle position, so that neither mark appears; then push H 1 and wind up the cylinder by a key at the left; push H 2 and it is locked; and lastly draw the carriage into its first position.

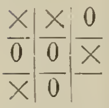
We make our move by putting an instrument like an awl into one of the holes of the arcs, and so moving it that the cross appears. Suppose we move 2, then slider T 2 goes forward. Release the cylinder from the catch by pushing H 1. The cylinder turns until the pin at T I 2, line 22, strikes the slider. On pushing H 2 forward, the pin at U 5 will stop the slider *U* 5, and *X* 5 will push *R* 5 and *B* 5 forward. Then the wire *E* 5 from *B* 5 to *A* 5 will so move the arc that the zero (0) will appear at the opening 5. At the same time the slider *Ux* will move forward and lock the cylinder. When *H* 2 comes back, the carriage will move into position II, opposite the column T II. Suppose we then move 1, the cylinder will stop at line 23, and the machine moves 3, the carriage taking position III. If we now move 7, the cylinder will stop at line 24, the machine moves 4, and the carriage takes position IV. If we move 6, the cylinder stops at line 25, and the machine moves 8. [If we had moved 8 or 9, the cylinder would have stopped at line 26, the machine would have moved 6 and won. The pin on *U*0 causing the bell to strike.] Finally we move 9, and the game is drawn. The machine is then wound up.

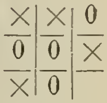




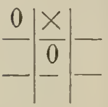


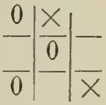


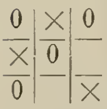


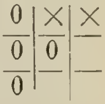


If we wish the machine to begin, we move one of the arcs so that the zero appears. Suppose that we so move 1. The slider *T* 1 is moved backward, hence *S* 1 is pushed forward by *Y* 1, and *K* pulls the catch from the cylinder, which turns until the pin at S 1, line 75, strikes the slider *S* 1. Then we make our move, suppose it to be 2. On touching *H* 1, the cylinder remains at line 75, and on pushing *H* 2, the machine moves 5, the carriage taking position II. Now, if we move 9, the cylinder stops at line 76, and the machine moves 7, the carriage taking position III. If we then move 4, the cylinder stops at line 77, the machine moves 3 and wins, the bell proclaiming the fact; but, if we move 3, 6 or 8, the cylinder stops at line 79, the machine moves 4. So it wins in either case.









This machine, the first one ever constructed, was built in the summer of 1878, and exhibited at the Franklin Institute, October 16, 1878. It is now at the University of Pennsylvania, where, since its final adjustment, it has played a large number of games without losing a single one.

PHILADELPHIA, *November 8th*, 1878.

DOES THE WEARING POWER OF STEEL RAILS INCREASE WITH THE HARDNESS OF THE STEEL?*

By Chas. B. Dudley, Ph. D.,
Chemist, Pennsylvania R. R. Co., Altoona, Pa.

While working, during the summer of 1877, upon the "Chemical Composition and Physical Properties of Steel Rails," the results of which are given in my report† with this title, I was struck with the surprising wear which some of the rails, which would ordinarily be called soft rails, had endured. At that time I knew of no chemical measure of softness except low carbon, and I found that a number of rails with low carbon had endured as high or higher tonnage, with apparently as little loss of metal by wear, as those with higher carbon. My own work on steel rails that summer did not embrace any definite experiments as to the amount of metal worn off the rail per million tons which had passed over it; and so I could get no more definite answer from that work, to the question at the head of this paper, than was given by comparing the appearance of the worn section of the rail with its tonnage. This comparison, however, served to arouse in my mind the query, whether the commonly received opinion as to the relation between the hardness and wearing power of steel, is correct, as applied to steel rails. This opinion, if I am right, is: the harder the steel, the better will be the wear, and the limit of hardness is simply one of safety; hard, brittle steel being, of course, more liable to break than soft, tough steel. The query, although aroused, did not bear any immediate fruit, and, as will be evident to any one reading it, the report above referred to was written with the commonly received opinion in mind. Since that time I have collected a little information upon this subject, which I should be glad to submit to the Institute, if for no other purpose, for the sake of arousing attention, and directing study to the question of hardness *versus* wear in steel rails.

Before making known the information, however, permit me a few words in reference to hardness. How shall we measure the hardness of steel? Of the various ways of getting indications as to the hardness of steel, which are known, three will serve our present purpose. These are: 1st. High carbon. It is generally agreed, I think, that at least within proper limits, the greater the amount of combined carbon in a piece of steel, the harder the steel, and I need not do more than mention this fact to obtain your assent to it. 2d. The physical test of punching, measures the hardness of steel. Data in regard to the wearing power of hard and soft rails, determined in this way, will be given below. 3d. The sum of the phosphorus units in a piece of steel measures its hardness. Phosphorus units, as is fully described in my report above referred to, are an attempt to measure the hardness of steel by estimating the combined hardening power of the phosphorus, silicon, carbon and manganese in a piece of steel, in terms of the phosphorus. Now, by measuring hardness in these three ways, I have been able to collect the following information with regard to the relation between the hardness and wearing power of steel rails.

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* A paper read before the Institute of Mining Engineers, October 15th, 1878.

† See vol. cvi, page 361.

1. Some two years ago the Penna. R. R. Co., in view of the unsatisfactory wear it was obtaining from its steel rails, asked to have more carbon put into its rails, with a view of making them harder, to resist wear. Before the increase, the limits of carbon for rails to be used on Penna. R. R., was from 0·30 to 0·50 per cent. After the increase, the limits were from 0·40 to 0·50 per cent., thus securing on the average perhaps, about a tenth of a per cent. more carbon in the steel. Now, Mr. W. H. Brown, Chief Engineer, Maintenance of Way, Penna. R. R., informs me that these rails of higher carbon are giving poorer wear than before the lower limit of carbon was raised. This opinion of Mr. Brown is based on his observation of the wear of these higher carbon rails, and on the number of renewals of these rails, rendered necessary by the condition of the track.

2. Mr. J. T. Smith, General Manager of the Barrow Hæmatite Steel Works, England, read a paper on "Bessemer Steel Rails," before the Institution of Civil Engineers, in 1875.* The object of the paper was to show that Bessemer steel may be produced constant in quality, and that certain inexpensive tests may be applied, which shall determine the quality of the metal for railway purposes. The test proposed by Mr. Smith was to punch the fish-plate holes with a registering-press, the quality of the metal being judged of by the

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* Proceedings Inst. Civil Eng., vol. xlii, p. 69.

force required to punch the holes. This would render it possible to inspect and judge of the quality of every single rail. I must refer you to Mr. Smith's paper for further information upon this point.

The point which is of especial interest to us now is that Mr. Smith examined thirty rails which had been eight years in service on the main line of the Furness Railway. The rails were divided into two classes, on the basis of the force required to punch a hole $\frac{7}{8}$ of an inch in diameter, through the web $\frac{3}{4}$ of an inch thick. Twenty of the rails required for this purpose a force varying from $46\frac{1}{4}$ tons to $52\frac{1}{2}$ tons, and were therefore called soft rails; while the remaining ten rails required for the same purpose a force varying from $56\frac{3}{4}$ tons to $82\frac{1}{2}$ tons, and were therefore called hard rails. The average force required to punch the soft rails was about 49 tons, while for the hard rails this average force was about $64\frac{3}{4}$ tons. Mr. Smith likewise gives the determinations of the carbon in these rails. In the twenty soft rails the carbon varied from 0·28 to 0·32 per cent., or an average of 0·30 per cent., while in the hard rails the carbon varied from 0·36 to 0·57 per cent., with an average of 0·44 per cent. Now as to the wear of these rails. The wear seems to have been determined by taking the difference between the original weight of the rail per yard, and the weight per yard of the worn rail, and then reducing this to the percentage of the metal worn off. Now in the twenty soft rails, this percentage of wear varied from 10·38 to 16·24 per cent., with an average wear of 13·54 per cent., while in the ten hard rails the percentage of wear varied from 12 to 20·53 per cent., with an average of 15·18 per cent. These figures seem to me very significant, and to warrant Mr. Smith in the conclusion which he expresses, viz.: "Contrary to what might have been anticipated, greater hardness has not conduced to the longevity of the rails, and the softer ones show the minimum of wear."

3. With regard to the wear of rails, in which the hardness is measured in phosphorus units. On May 23d, 1876, Mr. R. Price Williams read a paper before the Institution of Civil Engineers, on "The Permanent Way of Railways." * In his investigation into the subject of steel rails, Mr. Williams found such a surprising difference in the wear of certain rails which were side by side, and therefore subjected to the same traffic, that he had seven of these rails from the Great Northern Railway analyzed by Mr. Edward Riley. The

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* Proceedings Inst. Civil Eng., vol. xlvi, p. 147.

results as to wear are given in number of million tons traffic per $\frac{1}{16}$ inch worn off the rail. Four of these seven rails, measured in phosphorus units, sum up 31, 30, 32 and 25, and may, therefore, be called, in comparison with the others, soft rails. The remaining three rails sum up, in phosphorus units, 38, 40 and 47, and may be called hard rails. The rails are numbered, in Mr. Williams' series, Nos. 9, 17, 18, 21, 22, 23 and 24. Nos. 17 and 18 were side by side, and subjected to the same traffic. The phosphorus units in No. 17 are 38, and in No. 18, 30, one hard and one soft, as is seen. The hard rail withstood 5,251,000 tons per $\frac{1}{16}$ inch wear, while the soft one withstood 8,402,000 tons per $\frac{1}{16}$ inch wear. Again, Nos. 23 and 24 were side by side. The phosphorus units in No. 23 were 47, and in No. 24, 25, one hard and one soft, as before. The hard rail withstood 15,531,000 tons per $\frac{1}{16}$ inch wear, while the soft rail withstood 31,061,000 tons per $\frac{1}{16}$ inch wear. In Nos. 21 and 22, which were side by side, the hard rail shows a little the best wear, the figures being 9,283,000 tons per $\frac{1}{16}$ inch wear, for the hard rail, and 7,676,000 tons per $\frac{1}{16}$ inch wear for the soft rail. If now we take the average of the tonnage per $\frac{1}{16}$ inch wear for the three hard rails and the four soft ones, the result becomes quite striking. The four soft rails withstood an average tonnage of 15,567,000 tons per $\frac{1}{16}$ inch wear, while the three hard rails withstood, on the average, only 10,055,000 tons per $\frac{1}{16}$ inch of the metal worn off. The chemical composition of the one rail of this series, which withstood the highest tonnage, viz., 31,061,000 tons per $\frac{1}{16}$ inch wear, is so remarkable that I cannot forbear quoting the full analysis. This rail sums up 25 in phosphorus units, and contains: carbon, 0·270 per cent.; phosphorus, 0·100 per cent.; silicon, 0·020 per cent.; manganese, 0·259 per cent.; sulphur, 0·051 per cent.; copper, 0·025 per cent.; and iron, 99·475 per cent.

If enough has been said upon this subject to direct attention to it, my object will have been accomplished. It is perhaps too soon to venture conclusions. The indications would seem to be, however, that under the conditions of wear to which a steel rail is subjected, viz., rolling friction, unlubricated surfaces, and great weight with small bearing surface, the quality of the metal necessary to most successfully withstand the disintegrating forces, is best expressed by the word toughness, and not by hardness.

ALTOONA, PA., *Oct.* 12*th*, 1878.

WATER-TUBE AND FIRE-TUBE BOILERS.

An Account of the Experiments made by Chief Engineers Loring and Baker, U. S. Navy, on a Horizontal Fire-Tube and a Vertical Water-Tube Boiler, at the Washington Navy Yard, to ascertain their relative Economic Vaporizations with different kinds of Coal.

By Chief Engineer Isherwood, U. S. Navy.

At the time the compound engine was introduced into the Navy of the United States, several modifications were attempted of the ordinary cylindrical boiler habitually employed with it. These modifications were made for the purpose of obtaining either better economic vaporizations, or of placing the grate and heating surfaces in a less breadth of shell; and among them was an arrangement, in a cylindrical shell, of vertical water-tubes immediately over the furnaces, in exactly the position occupied by the horizontal fire-tubes of the ordinary boiler.

This system of vertical water-tubes which had been introduced with rectangular shells into the steamers of the United States Navy some eight years before the writer became Chief of the Bureau of Steam Engineering in the Navy Department, was continued by him after careful experiments had proven that, with such proportions as were practicable for marine boilers, the vertical water-tube gave the best economic vaporization; in other words, a pound of coal burned in the vertical water-tube boiler vaporized more pounds of water than when burned at the same rate in a horizontal fire-tube boiler having the same proportions.

The vertical water-tube boiler which was originally invented by the Earl of Dundonald, had been perfected in its constructive details by Chief Engineer Daniel B. Martin, of the United States Navy, and was known in America as the "Martin Boiler." It was, with the exception of a few merchant steamers, used exclusively in the Navy, where it always gave the greatest satisfaction; but in Great Britain it never obtained the like success. The large steam-engine building firms, both there and in America, opposed its use, though certainly without regard to its engineering merits. These firms take contracts for a round sum to produce either a stipulated horse-power, or a stipulated speed of vessel over a measured mile, independent of the weight of coal consumed; and as the vertical water-tube boiler is much heavier, more bulky and more costly for equal maximum weights of steam supplied per hour, and as they pay for the construction of the boiler, and not for the coal it consumes, they naturally prefer the cheapest type.

The vertical water-tube boiler obtains a greater economic result from the coal, solely by virtue of the superior arrangement of its tubes for heat absorption; the furnace and smoke-connections being the same as in the ordinary type, and the position of the tubes relatively to them being also the same, whatever difference may be found in the economic result, must be entirely due to the tubes. In other words, of a given quantity of heat of given intensity thrown upon equal tube-surface in the two types of boiler in equal time, the vertical water-tubes will absorb more than the horizontal fire-tubes; and, as a necessary consequence, the gases of combustion will enter the chimney at a lower temperature and produce a less draught. One reason why the vertical water-tubes are more absorbent of heat than the horizontal fire-tubes, is that the former stands across or at right angles to the current of the gases of combustion, thereby continually breaking it up and commingling its constituents, each row of tubes being as a consequence impinged on by freshly mixed gases as they proceed from the back smoke-connection to the uptake; while the horizontal fire-tubes, lying in the direction of this current, have no such mechanical action upon it, the particles of the hot gases entering at the smoke-connection end of a horizontal fire-tube retain their relative positions until they emerge from its uptake end, so that the same particles are in contact with the tube-surface from one end to the other during the second or two of their passage. Thus, the core, or central mass of the gases in each tube, may have at its exit a much higher temperature than its surrounding film in contact with the tube-surface; while, in the vertical water-tube boiler, the mass of horizontally moving gases emerging into the uptake must have a nearly uniform temperature due to their thorough mixture by beating against and eddying around the vertical tubes which obstruct their progress. It is highly probable, too, that the intimate intermingling of the gaseous current from the furnaces, effected by this mechanical action of the vertical water-tubes, causes the combustion of a portion of its constituents which might otherwise escape combination. Of course, the obstruction opposed by the vertical water-tubes to the current of the gases of combustion, mechanically lessens the draught of the chimney in addition to the lessening that results from the lower temperature of those gases comparatively with that of the gases entering the chimney from the horizontal fire-tube boiler; so that the vertical water-tube boiler has a less draught than the horizontal fire-tube boiler, both by the amounts due to the lessened temperature of the current of gases of combustion entering the chimney and due to the mechanical obstruction opposed to that current by the tubes as a consequence of their position. Hence, other things equal, the maximum rate of combustion in a vertical water-tube boiler is less than in a horizontal fire-tube boiler, and a greater quantity of the former is required to supply at the maximum the same quantity of steam in equal time as the latter, notwithstanding the greater vaporization per pound of coal consumed in the former. The greater economic efficiency of the vertical water-tube boiler and its less potential efficiency, are thus inseparably joined as cause and effect when the draught is controlled by the chimney alone; but when mechanical means are employed to produce the draught, as a fan-blower for example, then, both in economic and potential efficiency is the vertical water-tube boiler superior to its rival.

In general, as the result of his very extended and carefully conducted experiments, the writer found that, other things equal, the rate of combustion at the maximum by the chimney alone in the case of the horizontal fire-tube boiler, was 50 per centum greater than in the case of the vertical water-tube boiler; but, that the economic vaporization at those relative rates was 25 per centum less than in the latter. Hence, for equal quantities of boiler, the horizontal fire-tube produced in equal time, at the maximum 25 per centum, more steam than the vertical water-tube, but at an expense of 25 per centum more coal per pound weight of steam. In this fact will be found the principal reason of the little use by contractors for steam machinery of the vertical water-tube boiler; and their practice may, in measure, be defended for steamers making short voyages, but just in proportion as the voyages lengthen does that practice cease to be judicious. The engineer has to look upon the boiler and the coal to be carried as a whole, with a proportion between them variable according to circumstances. He has to consider that a certain space and displacement are allotted in the vessel to the two combined, and it is a test of his skill to so proportion them to each other, for the different types, as to obtain from them the greatest number of miles steaming. The greater the economic efficiency of a certain type of boiler, though accompanied by a less potential efficiency, the more of it and the less of coal can be properly placed in the vessel to steam a given distance at a given speed; and the less the economic efficiency of a certain type of boiler, though accompanied by a greater potential efficiency, the less of it and the more of coal can be properly placed in the vessel to steam the given distance at the given speed. The best type of boiler to be adopted, is the one which enables the vessel, with a given space and displacement assigned to boiler and coal, to make the given distance at the given speed, with the least coal. Hence, for naval steamers making long voyages, the vertical water-tube boiler gives better results than the horizontal fire-tube boiler, and better just in proportion to the number of days the vessel is required to be able to steam at the given maximum speed. Such were the considerations which led the writer to prefer the vertical water-tube boiler to the horizontal fire-tube boiler for the steamers of the United States Navy, and he believes their soundness will bear the closest scrutiny. The boilers he designed had rectangular shells, and were braced for a working pressure of 40 pounds per square inch, above the atmosphere; they allowed about 50 per centum more grate and heating surfaces to be placed in a given space than the cylindrical boilers carrying a pressure of 70 pounds; and it is very doubtful if any economic gain possible from the latter pressure can compensate the enormous increase of space required, especially when the value of space in a naval vessel is considered.

Compared with the horizontal fire-tube boiler, the vertical water-tube boiler, when steaming at the maximum over a given distance in a given time, is 25 per centum heavier, more bulky and costly; but it requires 25 per centum less weight of coal carried in the bunker. In weight and bulk, this less weight of coal offsets in measure the greater weight and bulk of the boiler, and if the time of steaming extends to eight or ten days, much more than offsets them, while the much greater cost during a year's steaming of the 25 per centum additional coal with the horizontal fire-tube boiler, more than offsets the difference of cost between it and the vertical water-tube boiler.

The circulation of the water and the extrication of the steam over the *entire* tube-surface, are much more rapid with the vertical water-tube than with the horizontal fire-tube boiler; and, from these causes, the unit of surface in the former is much more efficient as a steam-producer, than the unit of surface in the latter.

All the water vaporized by the vertical water-tubes, is supplied to them from the space between the crown of the furnace and the lower tube-plate, and, in ascending, is not obstructed by any mechanical impediments, but, being guided by the vertical tubes themselves, takes the shortest path, and rises with the maximum velocity due to the conditions of temperature and height of column, passing with this velocity over the *entire surface of the tubes.* Hence, in a given time, the greatest possible number of particles of water would be brought in contact with a given tube-surface, and the bubbles of steam formed on that surface would be swept off by that rapid circulation, with corresponding speed. These advantages accrue to the vertical water-tube by reason of the parallelism of the tube with the ascending column of water, and by reason of the tube protecting the entire ascending mass of water from being broken in upon by lateral currents.

But with the horizontal fire-tubes, these conditions are all reversed. Those tubes, lying at right angles to the ascending current of water, act as mechanical obstructions, and consequently impede its velocity; beside which, the water vaporized by the horizontal tubes is supplied to them, not only vertically from the water space between the lower row of tubes and the crown of the furnaces, but horizontally from the water spaces at the sides of each group of horizontal fire-tubes, and coming in between the rows as cross-currents to the ascending mass, break in upon and lessen its vertical velocity. Neither the vertical nor the horizontal cross-currents can pass with maximum velocity over the *entire surface* of the horizontal tubes, because that surface being convex in opposition to these currents, can have only a line swept tangentially by them with the maximum velocity, which, existing only in the *least* water spaces between the tubes, is able to sweep only a line of their surfaces vertically and horizontally. There must be, therefore, in a given time, fewer molecules of water brought into contact with a given tube-surface in the case of the horizontal fire-tube, than in that of the vertical water-tube.

With the vertical water-tube boiler, brass tubes are indispensable, as iron ones last only from one to two years, owing to the rapid corrosion of their lower ends. The lower one-fourth of an iron vertical water-tube will be corroded entirely through, while the upper three-fourths will be unaffected, but brass tubes will much outlast the boiler. The corrosion of the iron tubes is nearly as rapid with jet condensers as with surface condensers, as it takes place almost entirely on the outside, being due to the sulphuric acid formed by the union of the sulphurous gases from the coal, with the moisture deposited on the tubes during each interval of steaming. This weak sulphuric acid trickles down the tubes, and remains around their lower ends, where there is also, generally, most soot. When, as sometimes in land boilers, the steaming is continuous the year around, with only occasional interruptions for cleaning, the iron vertical water-tube is as durable as the iron horizontal fire-tube, but it should never be employed with marine boilers.

The sweeping and replacing of vertical water-tubes are a little more difficult than in the case of horizontal fire-tubes; but they are far easier to be cleaned of scale, which can be entirely removed from the interior of water-tubes, but only partially from the exterior of fire-tubes; and the former have the advantage that the water level can be allowed to fall fifteen inches below their upper tube-plate, without injury from heat.

The vertical water-tubes require for their extraction and replacement, a height between their upper tube-plate and the boiler shell equal to their length. This condition cannot be had in a cylindrical shell, but if brass tubes are properly put in and well cared for, there will be no occasion to replace one during the life of the boiler. In the original construction of the boiler, the tube-box can be made complete, independently, with the tubes secured in their plates, and the whole then riveted into place.

In the case of a horizontal fire-tube and of a vertical water-tube boiler differing only in the tubes, all the other portions being the same, and the total grate and heating surface in the one being the same as the total grate and heating surface in the other; the weight of the former will be a little less than the weight of the latter in metal alone, exclusive of the water contained, but if the water be included, then the weights of both boilers will be about equal.

A modification of the ordinary cylindrical boiler, with horizontal fire-tubes returned above the furnaces, called the "oval boiler," has been found convenient in practice as enabling the grate and heating surfaces to be placed in a less frontage. This so-called oval boiler has a semi-circular top and bottom of equal diameter, connected by flat vertical sides, making the height of the boiler greater than its breadth by the height of these sides which are, of course, tied across by braces. Such a shell is particularly well adapted for vertical water-tubes, the height of the flat vertical sides being made the same as the height of the tubes, the tube-boxes being placed directly between these sides, and braced to them.

EXPERIMENTAL BOILERS.

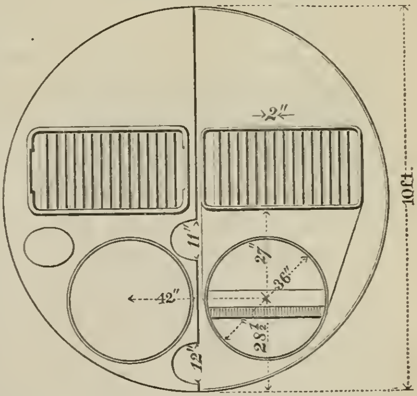
To test the mechanical feasibility, and the economic vaporization of such an arrangement of vertical water-tubes as could be placed in a cylindrical shell, comparatively with the economic vaporization by horizontal fire-tubes placed in a duplicate shell, the Bureau of Steam Engineering of the Navy Department, constructed at the Washington Navy Yard, two high-pressure boilers of the marine type, for compound engines. The shells of these boilers were cylindrical, 10 feet in diameter, and 9 feet in length, exclusive of their sheet iron uptakes. Each shell contained two cylindrical furnaces 3 feet in diameter, with grates 6 feet in length. The two boilers were duplicates in all respects except tubes, those in the one being horizontal fire-tubes, and those in the other being vertical water-tubes; but, in both cases, the tubes occupied the same position, immediately above the furnaces. The heating surface of the tubes has been calculated for their *inner* circumference in both cases, and with this method of calculation the total heating surface of the horizontal fire-tube boiler is 1019 square feet, or 28·30 square feet to one square foot of grate surface; while, in the vertical fire-tube boiler, the total heating surface is 1104 square feet, or 30·67 square feet to one square foot of grate surface. In quantity of heating surface, therefore, the vertical water-tube boiler exceeded the horizontal fire-tube boiler $\left(\frac{1104 - 1019 \times 100}{1019} =\right)$ 8·34 per centum, or about one-twelfth; but that this additional quantity had but very little influence on the economic vaporization, will be apparent when the rate of combustion (only 14·2 pounds per square foot of grate surface per hour, at the maximum) is considered, and the large proportion of heating to grate surface (28·30 to 1·00) existing with the boiler having the least heating surface. The cross area over the bridge-walls for draught, is the same in both boilers, namely 5·55 square feet, which is one square foot to each 6·40 square feet of grate surface. This proportion is the same through the tubes of the vertical water-tube boiler, but is much greater through the tubes of the horizontal fire-tube boiler, where it is one square foot of cross area to each 4·97 square feet of grate surface. This difference, in view of the fact that the cross area for draught over the bridge-walls is less than through the tubes, has no effect on the economic vaporization. The steam room in both boilers is of very nearly the same height and capacity.

The following is a detailed description of each boiler, together with its dimensions and proportions:

THE VERTICAL WATER-TUBE BOILER.

The shell of the vertical water-tube boiler is a cylinder with flat ends at right angles to its axis. This cylinder is 10 feet in diameter and 9 feet in length, externally; the uptake, which is of sheet-iron bolted to the front end of the cylinder, projects beyond this length. The plates of the shell are $\frac{11}{16}$ of an inch thick and double riveted. The flat ends of the shell above the tube-boxes are stayed directly across with iron rods $1\frac{5}{8}$ inches in diameter and 10 inches between axes, attached to double angle iron riveted vertically to the ends. All other flat ends are stayed with socket-bolts $1\frac{1}{8}$ inches in diameter and 6 inches between centres.

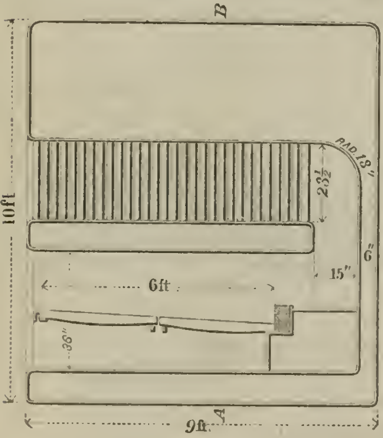
FIG. 1.



There are two furnaces contained in horizontal cylinders of 3 feet internal diameter and 7 feet 3 inches extreme length. The axes of these cylinders are in the same horizontal plane and 42 inches apart. The cylinders are composed of iron plates, $\frac{1}{2}$ inch thick, butted, and double riveted to inner welts below the grate-bars; they are single riveted to the boiler shell, and are in two lengths, flanged where the lengths meet at the centre and single riveted thereby. The grates within these cylinders are 6 feet in extreme length, composed of cast-iron in two lengths of 3 feet each. The bridge-wall is cast-iron faced with fire-brick, and is 6 inches high above the level of the grates. The top of the grates is 18 inches below the crown of the furnace at the front, and 21 inches below it at the back.

Each furnace has a separate back connection 15 inches long lengthwise the boiler, with its top rounded on a quadrantal arc of 13 inches radius. Its back is flat and separated from the back end of the boiler shell by a flat water-space 6 inches wide, including thicknesses of metal. The bottom of the connection is a horizontal extension of the bottom of the cylinder containing the furnace, and the sides are flat. The inner side is vertical and rises from the horizontal diameter of the furnace. The outer side, at top, is a horizontal extension of the vertical side of the tube-box, from the lower edge of which it slopes inwards on a tangent to the cylinder containing the furnace. The cast-iron bridge-wall of the furnace is extended clear across the connection, so as to occupy the whole of the lower portion.

Fig. 2.



Here are two horizontal tube-boxes, one to each furnace, and they are returned directly above the furnaces from the back connections to the uptake. These boxes are rectangular, $23\frac{1}{2}$ inches high and 47 inches wide in the clear, with an extreme length of 7 feet 3 inches. They are composed of $\frac{1}{2}$ inch thick iron plates, flanged and single riveted. Their tops and bottoms are the upper and lower tube-plates, and their sides are stayed to each other and to the boiler shell by socket-bolts. The space in the clear between the top of the cylinders containing the furnaces and the bottom of the tube-boxes is $8\frac{1}{2}$ inches.

Each tube-box contains four hundred and fifty vertical water-tubes of seamless brass $\frac{1}{10}$ of an inch thick, expanded on one side and riveted over on the other side of their tube-plates. These tubes are 2 inches in external diameter and $23\frac{1}{2}$ inches high in the clear between their tube-plates. They are arranged in fifteen rows crosswise the boiler, and thirty rows lengthwise the boiler; their axes being in straight lines, or not staggered. The distance between the axes of the tubes crosswise the boiler is 3 inches, and lengthwise the boiler 2¾ inches.

Both tube-boxes discharge into one uptake which, at the top, delivers the gases of combustion into a horizontal sheet-iron flue connecting the uptake of the vertical water-tube boiler with that of the horizontal fire-tube boiler, and from the centre of this flue the chimney, common to both boilers, rises. The uptake has the usual doors for access to the tubes for sweeping, etc.; and the furnace-doors were thoroughly perforated for the admission of air above the incandescent fuel on the grates.

The following are the principal dimensions and proportions of the vertical water-tube boiler:

Diameter of the shell,	10 ft.
Length of the shell, exclusive of the uptake,	9 ft.
Number of furnaces,	2.
Breadth of furnaces,	3 ft.
Length of grates,	6 ft.
Total area of grate surface,	36 sq. ft.
Total number of tubes,	900.
External diameter of tubes,	2 in.
Internal diameter of tubes,	1·80 in.
Length of tubes in clear of tube-plates,	23·50 in.
Total cross area for draught above the bridge-walls,	5·55 sq. ft.
Total cross area for draught through the tubes,	5·55 sq. ft.
Cross area, of the chimney,	12·57 sq. ft.
Diameter of the chimney,	4 ft.
Height of the chimney above the level of the grate-bars,	60 ft.
Heating surface in the two furnaces,	69·03 sq. ft.
Heating surface in the two back connections,	68·00 sq. ft.
Heating surface in the two tube-boxes,	131·10 sq. ft.
Heating surface in the 900 tubes, measured on their inner circumference,	830·55 sq. ft.
Heating surface in the one uptake,	5·32 sq. ft.
Total water heating surface in the boiler,	1,104·00 sq. ft.
Square feet of water heating surface per square foot of grate-surface,	30·67.
Square feet of grate-surface per square foot of cross area above bridge-walls,	6·49.
Square feet of grate-surface per square foot of cross area through tubes,	6·49.
Square feet of grate-surface per square foot of cross area of chimney,	2·87.

Water room to 6 inches above tubes, . . .	310 cu. ft.
Steam room from 6 inches above tubes, . . .	153 cu. ft.
Greatest height of steam room, ...	2·75 ft.
Weight of boiler, exclusive of uptake, chimney, uptake doors, furnace doors and frames, water, grate-bars, bridge-walls, etc., but inclusive of manhole and handhole plates, ...	30,605 pounds.
Weight of uptake, uptake doors and furnace doors, .	1,100 pounds.
Weight of grate-bars and bearers, ...	1,892 pounds.
Weight of cast iron bridge-walls and their brick facing, ...	810 pounds.
Weight of non-radiating cement covering for boiler,	6,000 pounds.
Weight of water in boiler, ...	19,323 pounds.
Total weight of boiler, exclusive of chimney, ready for service, ...	59,730 pounds.

(To be continued.)

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Concluded from Vol. lxxvi, page 246.]

The endeavors to produce matches entirely free from phosphorus, have continued without interruption since the investigation of Wiederhold,† which are of permanent value, and must be regarded as the basis of all subsequent enterprise in this direction. In the opinion of many, they have not yet been so far improved as to be on an equality with phosphorus matches. They are still too hard to strike, diffuse an unpleasant odor, and have no advantage in cheapness. The non-phosphoric matches, however, recently produced on the large scale by G. Kalliwoda,‡ are said to be totally or almost entirely free from these defects. This important problem may therefore be regarded as solved, if prolonged experience confirms the above favorable reports.

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* "Berichte über die Entwickelung der Chemichen industrie während des letzten Jahrzehends.

† Wiederhold, *Jahresber. f. Technol.*, 1861, 622.

‡ Kalliwoda, *Deutsche Industrie Z.*, 1871, 17.

According to C. Liebig, a good mixture, free from phosphorus, may be prepared as follows:—

Sulphuret of antimony, . . .	8 parts.
Chlorate of potash, ...	16 "
Red lead, ...	10 "
Bichromate of potash, . . .	1 "
Nitro-mannite, ...	8 "
Glass, ...	4 "
Gum arabic, ...	5 "

Particulars as to the value of this mass are unknown; it cannot be cheap, and the preparation may not be free from danger.

Among the non-phosphoric mixtures, must be included, that suggested by Fleck, containing finely divided sodium diffused in paraffin.

As ingenious as are the methods proposed to counteract the unfavorable attributes of the sodium, this proposal will in all probability never be practically realized, especially as better agents are known.

For blasting charges under water, Fleck's mixture might possibly be applicable, but the spontaneous decomposition which gradually sets in, would be found a difficulty. E. Kopp,* has already called attention to its disadvantages, whilst Springmühl, after a careful examination, and also Jettel, deny that it possesses any practical value.

At the Exhibition, France, Sweden and Austria represented the match trade.

On behalf of France, appeared the *Compagnie Générale des Allumettes Chimique*, formed in the month of October, 1872, and possessing the leading monopoly for the production of matches in the whole of France. For this privilege, it pays to the Government a fixed tax of 16,000,000 francs, as long as the consumption in France does not exceed 40 milliards. Beyond this consumption, there is a progressive duty of 6 centimes per 100 matches. Hence, this company alone, represents the whole of the match trade of France. The former manufacturers, in expectation of the expropriation which they had daily to await, did not exhibit. The importance of this manufacture for France, appears from the following figures.

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* Kopp, *Monit. Scientif.*, 1870, 74.

The number of the (former) match-works in France, large and small, amounts to no fewer than 833. The inland consumption, is on the average, five matches daily per head, or 70 milliards yearly. The company must, therefore, meet the enormous daily demand of 180 millions without maintaining the old 833 works in activity. It has, therefore, decided to concentrate the production in twelve establishments, which will be distributed in the country, according to the need of production and the convenience for procuring the necessary materials. It is of opinion that it will be possible to introduce into each of these works, all those improvements, industrial and sanitary, which science has pointed out as requisite.

Of the 180 millions of matches daily required, 150 millions are of wood, and 30 millions of wax. The former require yearly, 45,000 cubic metres of wood (oak, poplar, aspen, pine and birch), 1200 to 1500 tons of roll-sulphur, and 300 tons of phosphorus (1 ton = 1000 kilos.). The 30 millions of wax-matches, represent a yearly consumption of—

300,000 kilos. spun cotton.
300,000 " stearin.
60 tons of phosphorus.

To this, must be added the consumption of the other articles, such as red-lead, gum, etc., of which the company's report to the jury gives no account.

This daily production of 180 million matches, requires above 6000 workpeople, both men and women. The varied, more or less elegant, pasteboard boxes are manufactured by the company, 3 millions being required daily, requiring a yearly consumption of at least 2500 tons of pasteboard of various qualities. As to the number of work-people engaged in the production of these boxes, the report gives no particulars, but we may conclude from other sources that about 12,000 persons of both sexes will suffice, to whom must further be added those employed in packing and sending off, to the number of at least 200 persons.

The above figures refer merely to the home consumption, but there is also considerable exportation, not merely by sea, but even into other countries of Europe. The French marks, "Roche," "Causemille," "Meiffreu," are in request at La Plata, Buenos Ayres, Japan, Guatemala, Peru, etc. The exportation amounts to the yearly value of 15 mill. francs, and consists exclusively of wax lights and round wooden matches. The traffic of the Société Générale is therefore as follows:—

Domestic consumption,	65,000,000 frs.
Exportation,	15,000,000 "
	80,000,000

Which is distributed as follows:—

Duty on consumption,	35,000,000 frs.
Duty on exportation,	1,800,000 "
Allowance to dealers,	13,000,000 "
Cost of production and profit,	30,200,000 "
	80,000,000 "

Finally, must be remarked that in the show-case of the company Coignet, Père et Fils, exhibit matches with a friction-surface of amorphous phosphorus.

In few countries has the manufacture of matches reached such a development, and is still making such progress, as in Sweden. Swedish matches are known in all civilized countries, and so valued that counterfeits are sold as Swedish. The exportation, which was only 1,114,677 kilos. in 1865, and 2,896,398 kilos. in 1870, rose in 1871, to 4,281,395, and in 1872, to 6,059,601 kilos. The requisite chemicals are imported from England. The works at Jönköping alone produce yearly, matches of the value 1½ millions riksdaler (at 1 mark 14 pf. German), and the production of the remaining twenty-four establishments now in operation, may be of equal value. Besides, there are some manufactories engaged solely with the manufacture of fusee-wire.

The largest establishment at Jönköping, is the property of a joint-stock company. It was founded in 1845, and is driven by four steam-engines, of the joint power of 76 horses. In 1872, there were employed 255 men, 849 women, 105 boys and 141 girls, the two latter groups under eighteen years of age; together, therefore, 1350 persons. Of the workwomen, 688 were only periodically engaged in their own houses, and that with the manufacture of boxes.

The production is constantly increasing, and amounted in 1872 to 128,039,754 matches of different kinds, representing a value of 1,857,249 riksdaler. About four-fifths of the total production are exported. The company has founded a school, a reading-room, baths for the workpeople, and is now erecting cottages for their accomodation. It employs alone as many workpeople as all the rest of the Swedish match works, and paid in 1872, 360,514 riksdaler in wages.

In the sister-kingdom of Norway, the match trade has also taken root, although on a smaller scale. Amongst the countries in which this manufacture was earliest established, and has been remarkably successful, Austria must not be forgotten, although its production is now less extensive than that of Sweden. The exportation of matches, wax-lights, etc., amounts to, in the years—

1870, ...	46,684 kilos.
1871, ...	43,685 "
1872, ...	42,436 "

The decline of the trade is ascribed to heavy local taxation. There are at present 43 large and 79 smaller establishments in operation.

Other Applications of Phosphorus.—Phosphorus is employed not merely in the match trade, but in so many other branches, both in a free state and in numerous compounds, that we cannot undertake their exhaustive description. The scientific chemist uses this element in innumerable investigations, as, *e. g.*, in the preparation of methyl- and ethyl-iodide, which, thanks to the labors of A. W. Hofmann, have become indispensable agents in research, and have found extensive application in chromo-technics. For such purposes, amorphoic phosphorus is often used instead of the ordinary kind, since its reactions are as a rule less violent.

In pharmacy, phosphorus plays also an important part, although exclusively in the shape of one of its oxygen compounds, phosphoric acid. This acid is found to be an excellent medium for introducing into the organism, the iron neccessary for the formation of blood. For this reason, ferric pyrophosphate, which has no inky flavor, and indeed very little perceptible taste, has rapidly become a favorite medicine, and it is used in Grimault's iron-syrup, in Löflund's extract of malt, and in so called "iron-sugar." As a reagent for many substances belonging to the *materia medica*, phosphoric acid is also important. According to Kratschmer and Nowak,* it is the best test for atropin; according to C. Scheibler,† there is no better precipitant, for nearly all organic bases than phospho-tungstic acid, a combination of phosphoric and tungstic acids, equally available for scientific and technological purposes.

Particularly important is the method of Prof. E. N. Horsford, of Cambridge, U. S., for the preparation of bread without yeast, and consequently without fermentation, by means of phosphoric acid. Liebig * considers this invention "one of the most important and beneficial that have been made within the last ten years." Prof. Horsford, who, during his stay in Vienna, as an Exhibition juror, had the kindness to perform his process in the laboratory of the reporter, proceeds as follows:—White washed bone-ash, (3 parts) are treated with about 2·4 parts of sulphuric acid, from which the small amount of lead present in the commercial acid has been previously precipitated by dilution with 10 parts of water. It is thus converted into the well-known calcium phosphate [$CaH_2(PO_4)_2$], which still contains one-third of the lime in the bones. After removing the gypsum, the liquid, which also contains the magnesia of the bones, is concentrated to the consistence of honey, and when cold is mixed with 1 part of starch of any kind, thus forming when thoroughly kneaded together a crumbly mass, which, on exposure to a gentle heat, yields a white powder. To this is added bicarbonate of soda, in the proportion of 3 parts of the phosphate to 1 of the soda-salt. Dough is now prepared with flour, mixed with salt, and with the above-mentioned baking powder, worked up well together and baked in the usual manner.

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* Kratschmer and Norwak, *Vien. Acad. Ber.*, ii, 69.

† Scheibler, *Dingl. Pol. Journ.*, ccix, 141.

The carbonic acid thus liberated makes the bread light and porous, so that in this respect it differs, if at all, advantageously from that produced with yeast. If bicarbonate of potassa is used instead of the soda-salt, the bread has a better flavor, and this procedure would be the more rational, since the greater part of the potash is withdrawn from the flour in the separation of the bran. Heretofore, however, the high price of the potash-salt, stands in the way of this improvement. Leibig, however, proposes to substitute a mixture of the bicarbonate of soda, and chloride of potassium in the proportion of about 2 to 1 for the bicarbonate of potassa.

The advantage of a process so easily executed in every household, and the beneficial effects of this well-flavored bread upon digestion are so evident; that it would be superfluous to enter upon any detailed explanation. We may mention, however, that for armies in the field, the value of this bread must be incalculable, as it is peculiarly adapted to serve for a time as a substitute for animal food. In America, it is already produced in large quantities, and has become a substance of daily consumption. In the recent war it proved very useful. It is evidently possible to incorporate with this bread, by

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* Liebig, *Ann. Chem. Pharm.*, cxlix, 37, *Wagner Jahresber.*, 1869, 470.

additions suited to circumstances, all the constituents of blood in the necessary proportion.*

We may finally mention that phosphorus, notably modifies the properties of metals with which it combines directly, and in the case of such as are strongly electro-positive even with the development of fire. The circumstance has met with technological applications, especially in the case of copper, which, by the addition 1·2 to 1·5 per cent. of phosphorus (phosphor-bronze), becomes harder, tougher, more fluid on fusion, and resists external influences better, *e. g.*, the action of sea-water. A plate of this bronze, thus exposed for six months, lost only 1·158 per cent. of its weight, whilst a plate of the best English copper of equal size, lost in the same time 3·058 per cent.

In the works of the Stephenson Tube Company, at Birmingham, phosphorus-bronze has been produced on the large scale since 1865, and is used for tubes, barrels for fire-arms of all kinds, cylinders for calico-printing, etc.

Larger proportions of phosphorus, render copper white and perfectly brittle. What is the exact part which small quantities of phosphorus may play when alloyed with copper is not quite clear. It may, possibly, as Dumas supposes, act principally upon the oxides mixed with the copper, and which, when converted into phosphides, may contribute themselves in the mass, thus rendering it harder, tougher, and more elastic.

The phosphor-bronze, from the works of G. Höpner & Co., at Iserlohn, is already extensively used for the bearings of axles, for gun-barrels, plating, weights, etc. (See the paper on "Copper," in a subsequent part of this report.)

If phosphate of copper, obtained by precipitating sulphate of copper with the phosphate of soda, is mixed with charcoal and exposed to a strong red heat, a white brittle copper phosphide is obtained, very rich in phosphorus, by the aid of which alloys of any desired composition can be most advantageously obtained.

Phosphates have been experimentally used in the glass manufacture, but without any marked benefit. The glass takes a yellow color.†

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* See "Theory and Art of Bread-Making: A New Process without the Use of Ferment," by Prof. E. N. Horsford.

† Pelouze, *Ann. Chim. Phys.*, (4), v, 465.

NOTE ON THE TAPER OF CONNECTING-RODS.

By William D. Marks,
Whitney Professor of Dynamical Engineering, University of Penn'a.

In a recent work on the steam engine,* the writer made the following remark:

"It is customary to make round connecting-rods with a taper of about one-eighth of an inch per foot, from the centre to the necks, which should be of the calculated diameter. Experiment does not show an increased strength from a tapering form."

Passed Assistant Engineer C. H. Manning,† in a pleasant correspondence with the writer, differed from him, deeming it the better method to taper connecting-rods from the crank-pin end to the cross-head end, as "experience had shown that connecting-rods usually failed at the crank-pin."

Led by this remark to make a more thorough investigation into the stress upon connecting-rods due to their own inertia, than he had before deemed necessary, the writer submits the results, hoping they may be of interest to engineers engaged in the designing of mechanism.

The connecting-rod, if of *wrought-iron*, must be considered either, 1st, as a short column, tending to rupture by crushing, or 2d, as a long column, tending to rupture by buckling. The tendency to fail in tension, can be neglected as being much less than in the two cases mentioned.

In the first case it is obvious that tapering will not add to its strength, if we neglect the stress due to its inertia and weight.

In the second case, theoretically, if we disregard the stress in flexure due to the inertia and weight of the connecting-rod, the increase in its diameter will be a maximum at its centre. (See "Weisbach's Mechanics of Engineering," Sec. iv, Art. 267.)

The connecting-rod, if of *steel*, may be considered, 1st, as a tension-rod, tending to fail in tension, or 2d, as a long column, tending to rupture by buckling. The ability of steel to withstand a much greater stress in compression than in tension, avoids the necessity of considering it as a short column, failing by crushing. In both cases the inertia and weight of the rod are disregarded.

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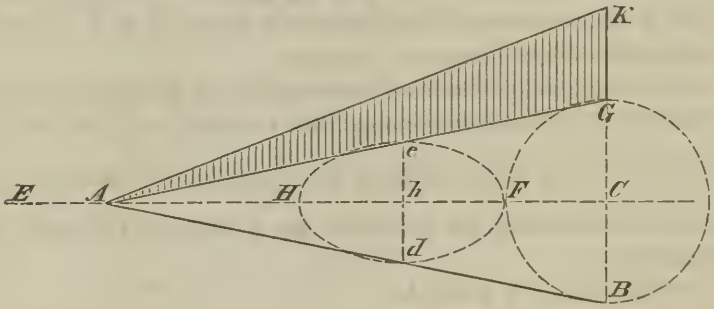
* The "Relative Proportions of the Steam Engine."

† Instructor in steam engineering, U. S. Naval Academy, Annapolis, Md.

These are the general conditions which have controlled the mechanical engineer in the consideration of the proportions of wrought-iron or steel connecting-rods. In addition, it has been customary in order to meet an unknown stress in flexure, due to the inertia of the rod, to increase the diameter of the rod at the middle, or latterly to give an increased diameter at the crank-pin, and taper from this to the smallest dimension of the rod at the necks or neck, this increase being purely empirical.

Prof. R. H. Thurston, of the Stevens Institute of Technology, in a personal letter, October 31st, 1878, says: "Where iron and steel are used, the figures adopted as constants must vary greatly, especially with steel. The value of E (modulus of elasticity) varies *enormously*," with which opinion the writer agrees perfectly, only regretting that the very basis of all correct calculations is thus taken from us, and we are forced to be contented with results which have a reasonable probability of correctness, if we assume average values for the safe stresses per square inch, and the moduli of elasticity of the material with which we are dealing.

Fig. 1.



If a straight line, $A\,B$, Fig. 1, have its extremities A and B respectively caused to move reciprocally upon the straight line $A\,E\,H$ and in the perimeter of the circle $B\,F\,G$, any point upon the line $A\,B$ as d will trace an ellipse as $d\,H\,e\,F$.

If, now, we let the length of the line $A\,B = l$; the radius $C\,B$ of the circle $= r$; the variable distance of the point d from the point

$A = A\,d = l_1$; we have the semi-major-axis of this ellipse $h\,F = h\,H = r$, and the semi-minor-axis $h\,d = h\,e = \frac{l_1}{l}r$, and the radius of curvature of the osculatory circle at the vertex d of the semi-minor-axis,

$$= R = \frac{l}{l_1} r. \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (1)$$

The maximum resistance due to its inertia of any small mass m at the end B of the rod $A\,B$, to motion in the direction $B\,C$, is equal to its centrifugal force

$$= c = \frac{m\,v^2}{r}, \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (2)$$

in which $v =$ the linear velocity of the point B in feet per second.

For a demonstration of this, refer to a paper by F. A. P. Barnard, Transactions of the American Institute.

Observing now that in the position shown in the figure, every point on the line $A\,B$ as d is moving with a velocity v in an arc of an osculatory circle, whose radius is $R = \frac{l}{l_1} r$, equation (1), we have the means of determining the resistance due to the inertia of each element of mass m.

For the point d it would be

$$\frac{m\,v^2}{R} = \frac{m\,l_1\,v^2}{l\,r}. \qquad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (3)$$

For the point A, since $l_1 = 0$, $R = \propto$, and the resistance of a mass m would be $= 0$. We thus see, equation (3) that the resistance of each element of mass due to its inertia to motion in a direction at right angles to $E\,A\,C$, is directly proportional to its distance $= l^1$ from the point A.

If, now, for the line $A\,B$ we substitute a rod of uniform cross-section $= F$, we have

$$m = \frac{F\,d\,l_1\,\gamma}{g}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (4)$$

in which $\gamma =$ weight per cubic unit, and $g = 32{\cdot}2$ feet per second, F being taken in square units.

Substituting this value of m in equation (3), and integrating between the limits $l_1 = 0$ and $= l$, we have, denoting the whole resistance of the rod $A\,B$ by P,

$$P = \int_0^l \frac{F \gamma v^2}{g\,l\,r}\, l_1\, d\,l_1 = \frac{F\gamma v^2}{2\,g\,r}\, l,$$

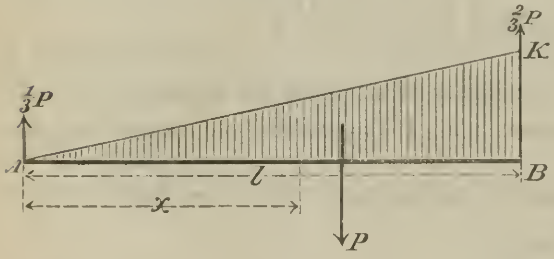
or since the weight of the rod $= G = F\gamma\, l$,

$$P = \frac{G\,v^2}{2\,g\,r}. \qquad (5)$$

And since this load upon the rod due to the resistance of its own inertia increases uniformly from the end A to the end B, the rod can, with sufficient approximation, be supposed in the condition of a horizontal beam loaded with a triangularly-shaped load, as shown, Fig. 2, in the cross-hatched portion $A\,K\,B$.

For a vertical engine, we can neglect the weight of the connecting-rod, considering only the stress due to its inertia.

FIG. 2.



For the moment of flexure of any cross-section at a distance x from the extremity A, we have, letting $c =$ the load per unit of length at the point K,

$$\tfrac{1}{3}\,P\,x - \tfrac{1}{6}\,\frac{c}{l}\,x^3 = \tfrac{1}{3}\,P\left(x - \frac{x^3}{l^2}\right), \qquad (6)$$

which becomes a maximum for $x = l\sqrt{\tfrac{1}{3}} = 0{\cdot}578\; l$, and at which point, therefore, the maximum cross-section of the connecting-rod should be placed.

In horizontal engines it is necessary to take into consideration the weight of the rod, as well as its inertia; the weight of the rod may be regarded as a uniformly distributed load, always acting in one direction.

For the cross-section, at a distance x from the extremity A, the moment of flexure is letting $G =$ whole weight of rod $= \gamma\, l$

$$(\tfrac{1}{3} P + \tfrac{1}{2} G)\, x - \left(\gamma \frac{x^2}{2} + \tfrac{1}{6} \frac{c}{l}\, x^3\right) =$$

$$(\tfrac{1}{3} P + \tfrac{1}{2} G)\, x - \frac{G}{2\,l}\, x^2 - \frac{P}{3\,l^2}\, x^3 \quad . \quad . \quad . \quad . \qquad (7)$$

which is a maximum for

$$x = -\frac{G\,l}{2\,P} \pm l \sqrt{\frac{1}{3} + \frac{G}{2\,P} + \frac{G^2}{4\,P^2}} \quad . \quad . \quad . \quad . \qquad (8)$$

But we have from equation (5),

$\frac{G}{2\,P} = \frac{g\,r}{v^2}$, in which $g =$ acceleration of gravity, $v =$ the linear velocity of the crank-pin, B, in feet per second, and $r =$ the radius of the crank in feet. Substituting this value in equation (8), we have,

$$x = l \left\{ -\frac{g\,r}{v^2} \pm \sqrt{\frac{1}{3} + \frac{g\,r}{v^2} + \left(\frac{g\,r}{v^2}\right)^2} \right. \quad . \quad . \quad . \quad . \qquad (9)$$

which shows that as the velocity of the crank-pin increases, the value of x approaches more nearly to $l\sqrt{\tfrac{1}{3}} = 0{\cdot}578\,l$, but can never quite equal it.

Referring to equation (7), and taking $P =$ zero, we find the maximum value of $x = \frac{l}{2} = 0{\cdot}5\,l$.

We thus see that the greatest moment of flexure of any connecting-rod lies between the limits $0{\cdot}5\,l$ and $0{\cdot}578\,l$, measured from the point A.

It is of interest further to note, that the crank-pin takes one-half the stress due to the weight of the rod, and two-thirds of the stress due to the inertia of the rod.

The end, A, takes one-third of the stress due to the inertia of the rod, alternately increasing and decreasing the stress upon the guides to this amount and one-half the stress due to its weight.

In engines having a large number of revolutions per minute, P becomes worthy of notice. In slow-moving engines it is very small, and may be neglected.

From these considerations, the writer is of the opinion that the failure of connecting-rods, at the neck nearest the crank-pin, *if they are properly proportioned*, is probably due more to the crank-pins being out of truth, rather than to the weight or inertia of the rods themselves.

He further takes this opportunity to state, that in a properly proportioned engine of any assumed horse-power, the *only* method of diminishing the weight of the moving parts, is to increase the number of strokes—lengthening the stroke will not do it.

December 7th, 1878.

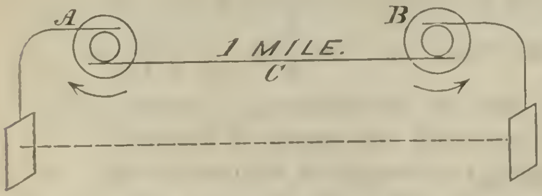
ON THE TRANSMISSION OF POWER BY MEANS OF ELECTRICITY.

By Profs. Elihu Thomson and Edwin J. Houston.

The statements recently made as to the size and cost of the cable that would be needed to convey the power of Niagara Falls to a distance of several hundred miles by electricity, have induced the authors to write the present paper, in the hope that it may throw light upon this interesting subject.

As an example of some of the statements alluded to, we may cite the following, viz.: That made by a certain electrician, who asserts that the thickness of the cable required to convey the current that could be produced by the power of Niagara, would require more copper than exists in the enormous deposits in the region of Lake Superior. Another statement estimates the cost of the cable at about $60 per lineal foot.

Fig. 1.

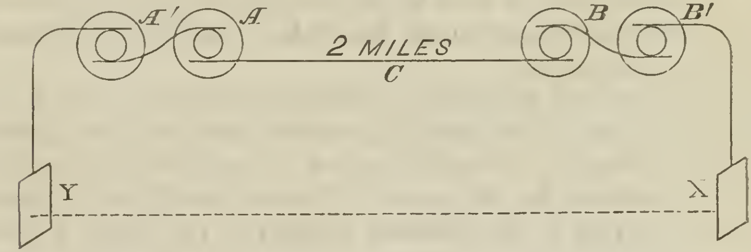


As a matter of fact, however, the thickness of the cable required to convey such power is of no particular moment. Indeed, it is possible, should it be deemed desirable, to convey the total power of Niagara, *a distance of 500 miles or more, by a copper cable not exceeding one-half of an inch in thickness.* This, however, is an extreme case, and the exigencies of practical working would not require such restrictions as to size.

The following considerations will elucidate this matter. Suppose two machines connected by a cable, of say 1 mile in length. One of these machines, as, for example, *A*, Fig. 1, is producing current by the expenditure of power; the other machine, B, used as an electrical motor, is producing power, by the current transmitted to it from A, by the cable C. The other terminals, x and y, are either put to earth, or connected by a separate conductor.

Let us suppose that the electromotive force of the current which flows is unity. Since by the revolution of B, a counter-electromotive force is produced to that of A, the electromotive force of the current that flows is manifestly the difference of the two. Let the resistance of A and B together, be equal to unity, and that of the mile of cable and connections between them, the ·01 of this unit. Then the current which flows will be $C=\frac{E}{R}=\frac{1}{1{\cdot}01}$. If now an additional machine, A', Fig. 2, and an additional motor, B', and an additional mile of cable, be introduced into the above circuit, the electromotive force will be doubled, and the resistances will be doubled, the current strength remaining the same as $C=\frac{E}{R}=\frac{1+1}{1{\cdot}01+1{\cdot}01}=\frac{2}{2{\cdot}02}$.

Fig. 2.



Here it will be seen that the introduction of the two additional machines, A' B', has permitted the length of the cable c to be doubled, without increasing the strength of the current which flows, and yet allowing the expenditure of double the power at A A', and a double recovery at B B' of power, *or, in other words, a double transmission of power, without increase of current.* Increase, now, the number of machines at A to say one thousand, and of those at B in like proportion, and the distance between them, or the length of the cable, one thousand, or in the case we have supposed, make it one thousand miles, its diameter remaining the same. Then although the same current will flow, yet *we have a thousand times the expenditure of power at one end of the cable, and a thousand-fold recovery at the* *other end, without increase of current.* And the same would be true for any other proportion.

Since the electromotive force is increased in proportion to the increase of power transmission, the insulation of the cable and machines would require to be proportionally increased.

As an example, it may be mentioned that a dynamo-electric machine used for the purpose of A in the figure, may have a resistance of say 40 ohms, and produce an electromotive force of say 400 volts. Such a machine might require from three to five horse-power when used in connection with a suitable motor B, for recovery of the power transmitted.

If the resistance of the motor B, be say 60 ohms, and the cable transmitting the currents a distance of one mile, be one ohm, then the current $C = \frac{400}{60 + 40 + 1} = \frac{400}{101}$. If now, one thousand machines and one thousand motors, and a thousand miles of cable, each of the same relative resistances be used, the current $C = \frac{1000 \times 400}{1000 \times 101}$, which has manifestly the same value as before. If our supposition of the power used to drive one machine be correct, then from three to five thousand horse-power would be expended in driving the machines, and possibly about fifty per cent. of this amount recovered. Then we have from 1500 to 2000 horse-power conveyed a distance of 1000 miles. What diameter of copper cable will be required for such transmission? Since this cable is supposed to have the resistance of one ohm to the mile, calculation would place the requisite thickness at about $\frac{1}{4}$ inch. If, however, the distance be only 500 miles, then the resistance per mile may be doubled, or the section of the cable be decreased one-half, or its diameter will be less than the $\frac{1}{5}$ inch.

For the consumption of 1,000,000 horse-power, a cable of about 3 inches in diameter would suffice under the same conditions. However, by producing a much higher electromotive force, the section of the cable could be proportionally reduced, until the theoretical estimates, which we have given in the first part of this paper, might be fulfilled. The enormous electromotive force required in the above calculation, would, however, necessitate such perfect insulation of the cable, that the practical limits might soon be reached. The amount of power required to be conveyed in any one direction, would, of course, be dependent upon the uses that could be found for it; and it is hardly conceivable that any one locality could advantageously use the enormous supposed power we have referred to.

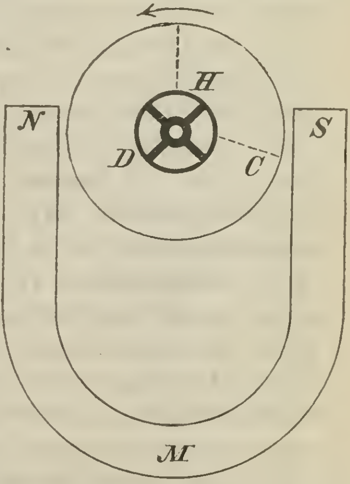
Stripped of its theoretical considerations, the important fact still remains, that with a cable of very limited size, an enormous quantity of power may be transferred to considerable distances. The burning of coal in the mines, and the conveyance of the power generated by the flow of rivers, may therefore be regarded as practicable, always, however, remembering that a loss of about 50 per cent. will be almost unavoidable.

It may be mentioned that Dr. C. W. Siemens, and Sir William Thomson, have recently made statements that are in general accordance with the views here expressed.

A CURIOUS THERMO-MAGNETIC MOTOR.

By Profs. Edwin J. Houston and Elihu Thomson.

During investigations by the authors, concerning the increase in the coercitive force of steel by changes of temperature, the following curious thermo-magnetic motor was devised. This motor, though devoid of practical value, will, no doubt, be of sufficient scientific interest to warrant a short description.



In the figure, a disc or ring of thin steel, *D*, is mounted on an axis, so as to be quite free to move. The edges of the wheel are placed opposite the poles *H* and *S*, of a magnet. In this position the wheel of course becomes magnetized by induction.

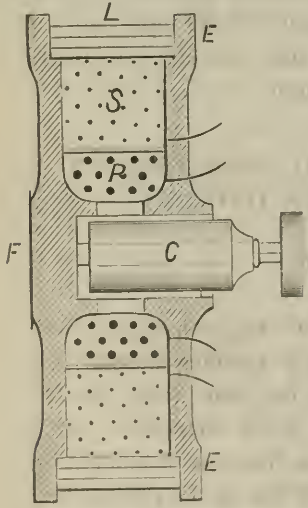
If now, any section of the wheel, as *H*, be sufficiently heated, the disc will move in the direction shown by the arrow. The cause of this motion is as follows: The section *H*, when heated, has its coercitive force thereby increased, and being less powerfully magnetized by the induction of the pole *S*, than the portion *C*, immediately adjacent to it, the attraction exerted by the pole *S* on the latter portion is thereby sufficient to cause a movement of the disc in the direction shown by the arrow. If a constant source of heat be placed at *H*, a slow rotation in the direction shown is maintained.

To ensure success, the disc must be sufficiently thin as to prevent its acquiring a uniform temperature. If the source of heat be at the same time applied at diametrically opposite portions of the disc, as at *H* and *D*, adjacent to the poles, the same effect will be produced. Since the amount of heat expended in producing motion of the disc is so enormous when compared with the force developed, it will be readily understood that this motor is of no value as such, but must be regarded as an interesting example of the interconvertibility of force.

INDUCTION APPARATUS FOR REVERSED CURRENTS.

By Profs. Elihu Thomson and Edwin J. Houston.

The following apparatus was devised by the authors for the purpose of obtaining induced reversed currents for use in electric illumination. These currents we use with a vibrating lamp, somewhat similar in construction to a lamp, a description of which has already been published.



Our method of operation is as follows: A reversed primary current is caused to induce reversed secondary currents in secondary coils provided therefor. These secondary currents are caused to give vibrations to carbon electrodes, and thereby at the same time produce a partial arc between them. With sufficient strength of primary current, a considerable number of secondary currents are obtained, each of which is able to operate one of our vibrating lamps.

The use of a vibrating lamp admits of a wider ange in the size of the carbons employed. When a light of very moderate intensity is desired, the carbons are made of very small size, and are placed in a closed glass vessel for protection from the atmosphere. To moderate the brilliancy, opalescent glass is used.

To obtain the highest efficiency of inductive action from a set of primary coils, the following form of induction of coil was devised: The primary coil *P*, surrounding the core *C*, is provided with a secondary coil *S*, adjacent to it. The ends *E* and *F*, of the bobbin, are made of disks of iron concentric with the core *C*, and slit from centre to circumference. The outer extremities of these disks are connected by wires or sheets of iron *L*, to one another, forming, in this manner, an induction coil encased in iron, or one whose core has its north and south extremities magnetically connected. The strength of the current developed in the secondary coil is greatest when the core *C*, which is movable, is inserted so that both of its extremities are in contact with *E* and *F*. By withdrawing this core, the currents in the secondary coil may be weakened to almost any desired extent. This coil is best adapted to the use of primary currents whose direction is constantly changing. All the wire being completely surrounded by iron whose direction of magnetic polarization is rapidly changed, the highest inductive effect is thereby produced in the secondary coil.

The variations in the intensity of the induced currents will, of course, be followed by variations in the intensity of the light emitted by the lamp. The movement of the core may, therefore, be made to increase or decrease the intensity of the light.

THE EFFECT OF CONTINUED AND PROGRESSIVELY INCREASING STRAIN UPON IRON.

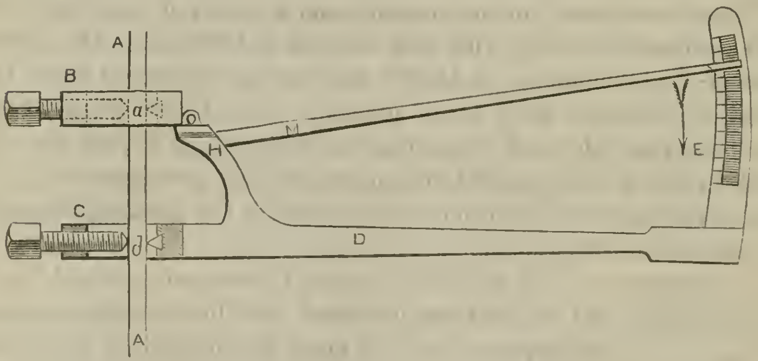
By Charles Huston.

I have observed repeatedly when a piece of iron was subjected to heavy strain in the testing machine, sufficient to produce more or less elongation, that if the strain was kept up for some time, say 24 hours or more, the iron underwent a change in its character. This change was shown in the fact that although an increase of elongation had been produced with each addition of 1000 lbs. to the square inch when applied without much interval, after the lapse of 24 hours it required 5000 lbs. to develop further elongation.

In order to investigate this subject with some system, I took five pieces from the same plate of bridge iron designated in the following table by Nos. 188, 189, 194, 195, 196. To enable the reader fully to understand, however, the details of the experiments, it is necessary to explain the apparatus used. The testing machine used was made by the E. & T. Fairbanks Co., the strain being produced by the screw, which I prefer because the power is positive, and whatever strain is developed, can be maintained for any length of time without the variation liable to occur from the leaking or other defects of the pump. The apparatus used for measuring the elasticity and permanent set, was devised by myself, and now under the control of the E. & T. Fairbanks Co., is shown in the accompanying figure.

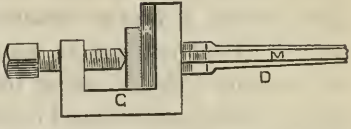
A, Figs. 1 and 2, represents the test-piece supposed to be fastened in the testing machine; *B* is a clamp which is attached to the test-piece between a knife-edge and a steel-pointed screw, thus establishing a fixed point at *a* on the test-piece; *C* is another clamp similar to *B*, and establishing another fixed point on the test-piece at *b*; the clamp *C*, however, carries a long arm *D*, which has at its outer end a graduated arc divided into inches, and each inch divided into 25 parts. Attached to the clamp *C* is the post *H*, which rises underneath the clamp *B* as near as possible, without contact; resting on this post is the indicator *M*, with a knife-edge bearing, Figs. 1 and 3, and measuring $\frac{1}{4}$ inch in length at the short end, and 10 inches at the long end, the short end resting in contact with the under side of the clamp *B*. When everything is properly adjusted, the length of the test-piece embraced between the two clamps should be just 2 inches; it is manifest, therefore, that any increase or decrease of distances between the points *a* and *b*, will cause the end of the indicator to fall or rise on the scale *E*, and with the measurements above, give an elongation of the test-piece between *a* and *b*, of $\frac{1}{1000}$ of an inch, will cause the indicator to fall one degree on the scale.

Fig. 1



When using this little apparatus, we shall find the moment we put any strain upon the test-piece it lengthens, but if the load is not made too great, the piece will contract to its original length on the removal of the load; this property I have named the *elasticity.** When, however, the indicator fails to return to its original position, it is an evidence that there has been a disturbance of the particles of the iron, and we then have two measurements: 1, the *degree of elasticity* as above, and, in addition, the next, 2, *degree of permanent set*, measured by the number of degrees the indicator fails to return after the load has been removed.

Fig. 2.

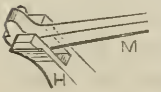


With this explanation, therefore, I return to the five test-pieces named above.

These were placed in the machine, and a record of both elasticity and permanent set kept with each increase of 1000 lbs. to the square inch of load, beginning at 10,000 lbs., but as the record below the point of permanent set is not of practical value, I have prepared the accompanying table and strain diagram, beginning at 27,000 lbs., the lowest point at which any of the specimens took permanent set. In the strain diagram there is no account taken of the *elasticity*, but only of the *permanent set.*

In specimen No. 188, as will be observed, permanent set took place at 31.000 lbs., and the load was increased 1000 lbs. at a time, without interruption, until the piece was broken; in the strain diagram, however, the elongation is not carried beyond ·030, that being the extent to which the little apparatus could measure; the total elongation, however, together with the tensile strength and contraction of area at point of fracture, are given at the foot of the table.

Fig. 3.



The next specimen, No. 196, took permanent set at 27,000 lbs., and was then kept at that strain for 24 hours; 1000 lbs. additional were then added, without increased permanent set; another 1000 lbs. were then added, and the permanent set was increased as before. This head (29,000 lbs.) was then maintained for 24 hours, at the end of which time another 1000 lbs. were added, with no change, but when the next 1000 lbs. were put on, it again elongated, and then

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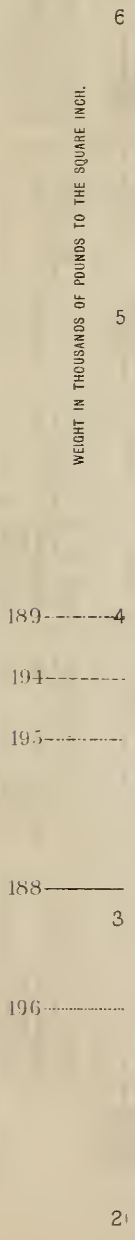
* The inherent property in bodies, by which they recover their former figure or dimensions after the removal of the external pressure or altering force.—Webster.

TABLE SHOWING THE EFFECT OF CONTINUED AND PROGRESSIVELY INCREASING STRAIN UPON IRON.

LOAD TO SQUARE INCH.	TEST PIECE No. 188.		TEST PIECE No. 196.		TEST PIECE No. 195.		TEST PIECE No. 194.		TEST PIECE No. 189.	
	Elasticity.	Perm. Set.	Elasticity.	Perm. Set.	Elasticity.	Perm. Set.	Elasticity.	Perm. Set.	Elasticity.	Perm. Set.
27,000	·00105	None.	* ·0012	·0001	·00145	None.	·0008	None.	·00105	None.
28,000	·0011	“	·0013	·0001	·00155	“	·00085	“	·0011	“
29,000	·00115	“	* ·0014	·0009	·00165	“	·0009	“	·00115	“
30,000	·0012	“	·0015	·0009	* ·00175	“	* ·00095	“	* ·0012	“
31,000	·0012	·0005	* ·00155	·00125	·0018	“	·001	“	·00125	“
32,000	·0012	·0007	·0016	·00125	·00185	“	·00105	“	·0013	“
33,000	·0012	·0009	* ·00165	·002	* ·0019	“	·0011	“	·00135	“
34,000	·0012	·0015	·0017	·002	·00195	“	* ·00115	“	·0014	“
35,000	·0012	·002	* ·00175	·00275	·00195	“	·0012	“	* ·00145	“
36,000	·0012	·0025	·0018	·00275	* ·002	·00115	·00125	“	·00155	“
37,000	·0012	·003	* ·0018	·0035	·00205	·00115	·00135	“	·0016	“
38,000	·0012	·0045	·00185	·0035	·0021	·00115	* ·00145	·0009	·00165	“
39,000	·00125	·006	* ·00185	·0047	* ·00215	·00415	·0015	·0009	·00175	“
40,000	·00125	·0095	·00185	·0047	·0022	·00415	·00155	·0009	* ·0018	·00105
41,000	·0015	·011	* ·00185	·00595	·00225	·00415	·00165	·00265	·00185	·00105
42,000	·0015	·016	·00185	·00595	* ·00225	·0106	* ·00185	·0044	·0019	·00105
43,000	·00175	·0185	* ·00185	·00845	·00235	·0106	·0019	·0044	·00195	·00105
44,000	·00175	·0255	·00185	·00845	·0024	·0106	·00195	·0044	·002	.00105
45,000	·002	·027	* ·0019	·0134	* ·0025	·022	·002	·0044	* ·002	·007
46,000	....	....	·0019	·0134	·0026	·022	* ·0021	·0134	·00205	·007
47,000	....	....	* ·00195	0134	·0027	·022	·0022	·0134	·0021	·007
48,000	....	....	·002	·0134	....	....	·00225	·0134	·0021	·007
49,000	....	....	....	....	....	....	·0023	.0134	·00215	·007
	Area, ·809 × ·365 = ·2953. T. S. to sq. inch 61,293 lbs. Elongation in 2″ = ½″ = 25 per cent. Contraction of Area = 25 per cent.		Area, ·830 × ·364 = ·3021. T. S. to sq inch 59,900 lbs. Elongation in 2″ = 15·6 per cent. Contraction of Area = 20 per cent.		Area ·829 × ·361 = ·2993. T. S. to sq. inch 58,800 lbs. Elongation in 2″ = 15·6 per cent. Contraction of Area = 18·3 per cent.		Area ·829 × ·361 = ·2993. T. S. to sq. inch 60,000 lbs. Elongation in 2″ = 13 per cent. Broke at flaw outside of the 2″.		Area ·807 × ·362 = ·2921. T. S. to sq. inch 66,415 lbs. Elongation 19 per cent. Contraction of Area = 29 per cent.	

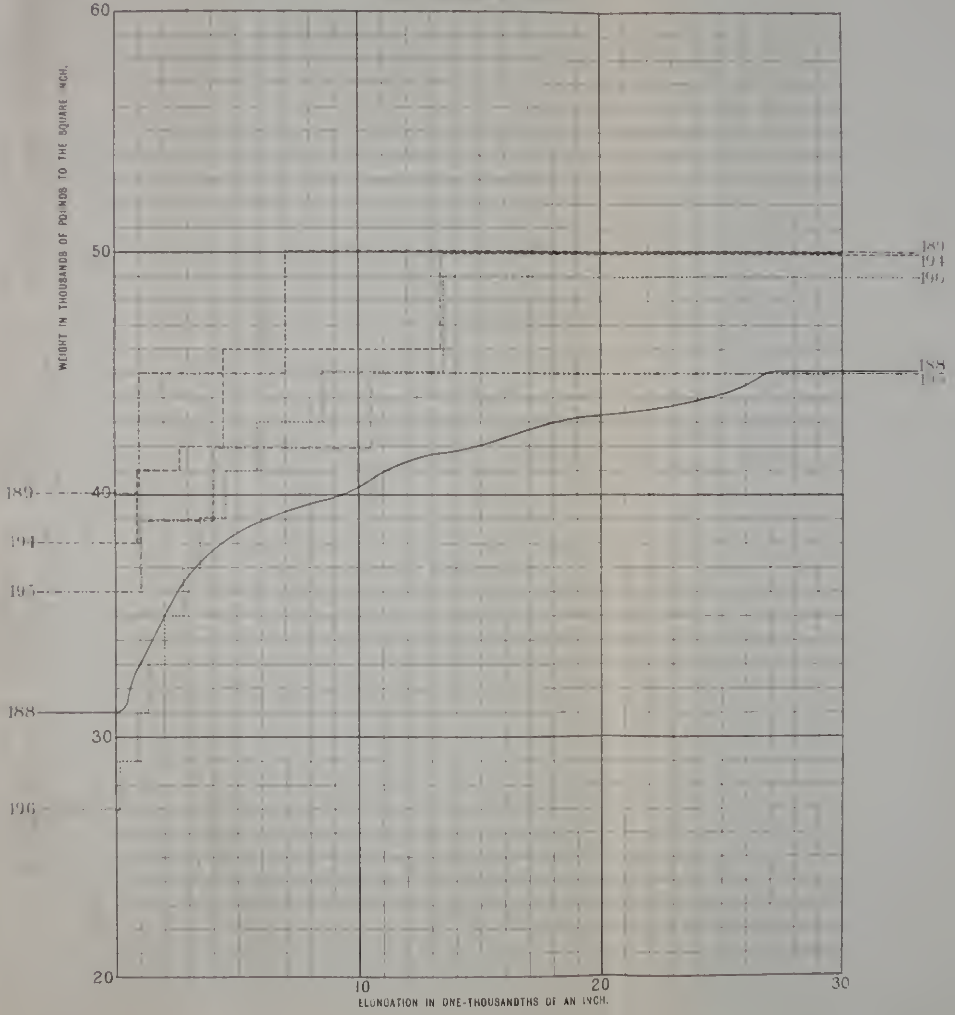
* Load carried 24 hours.


WEIGHT IN THOUSANDS OF POUNDS TO THE SQUARE INCH.
6
5
189
4
194
195
188
3
196
2

Journal of the Franklin Institute, Vol CVII.

THE EFFECT OF CONTINUOUS AND PROGRESSINGLY INCREASING STRAIN UPON IRON.

By Charles Huston.



kept at that strain for 24 hours, when the same process of increase of 1000 lbs. at a time was gone through with, showing no change with the first 1000 lbs., but an elongation at 2000 lbs., until I reached 47,000 lbs., when an increase of 2000 lbs. produced no change, but at 49,000 lbs. it again elongated, beyond the capacity of the instrument for measuring, and broke, with the record given at the foot of the table.

The next piece, No. 195, was loaded to 30,000 lbs., without permanent set, and kept at that for 24 hours; it was then loaded 1000 lbs. at a time to 33,000 lbs., still no change; after 24 hours, it was again loaded 1000 lbs. at a time, with no change until I reached 36,000 lbs., when elongation took place, and the machine was kept in equilibrium until stretching ceased; it was then kept for 24 hours, when 1000 lbs. were added at a time, with no change until I reached 39,000 lbs., and so after the expiration of 24 hours, it required an increment of 3000 lbs. each time to increase the permanent set. After completing the experiment, as shown, the next piece, No. 194, was taken and loaded to 30,000 lbs., with no change; after 24 hours it was again loaded 1000 lbs. at a time to 34,000 lbs., still no change; next day the load was again increased 1000 lbs. at a time, and no change until I reached 38,000 lbs., and each succeeding day it took 4000 lbs. to develop an increase of permanent set.

The next piece, No. 189, was then taken and loaded to 30,000 lbs., with no change; the next day to 35,000 lbs., and no change; the next day again, no change until I reached 40,000 lbs., and each succeeding day it required 5000 lbs. to increase the permanent set.

These results are very curious, and I fear will be difficult to believe, and, of course, must necessarily be taken *cum grano salis* until confirmed by repeated tests; but if they are true, it would seem as though a piece of iron might be loaded just beyond its so-called elastic limit, as in test-piece No. 196, and preserve its ductility or toughness so as to yield with every small increase of load; but that if you load a piece to very nearly its so-called elastic limit, and keep it there, it will become rigid and not elongate without a very decided increase of load, as shown by specimen No. 189; and it is admitted, I believe, by all engineers, that if you destroy the ductility of iron and subject it to concussion while under strain, it is very apt to break.

LUKENS' ROLLING MILLS, *Coatesville, Chester Co., Pa., Dec. 7th,* 1878.

THE JANNEY CAR-COUPLER.

From the Secretary's Report at the meeting of the Franklin Institute, Dec. 18th, 1878.

Large sums of money and a great amount of time have been spent in endeavors to devise a perfect system of connecting the cars of passenger railway trains, but the requirements are so numerous, and the difficulties to be overcome so great, that much the larger number of the efforts in this direction have proved failures.

The car-coupler invented by Mr. E. H. Janney, together with his automatic and double-acting compressing device, as applied to equalizing side-buffers, as shown in the accompanying figure, constitute a most complete system for this purpose, and one which is meeting with much favor with some of our leading railroads.

Fig. 1.

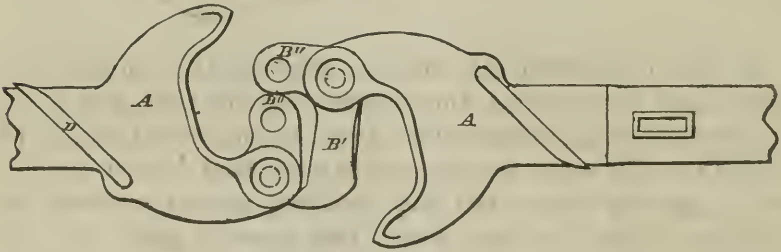


Fig. 1 is a top view of two couplers, represented as approaching each other for coupling.

In Fig. 2 two couplers are united; one in section, to show the internal arrangement of the parts.

Fig. 3 represents the knuckle, *B*, which, when in proper position, serves to hold the two couplers together.

Fig. 4 represents a plan of the platform, with the coupler, compressing device and side-buffers attached.

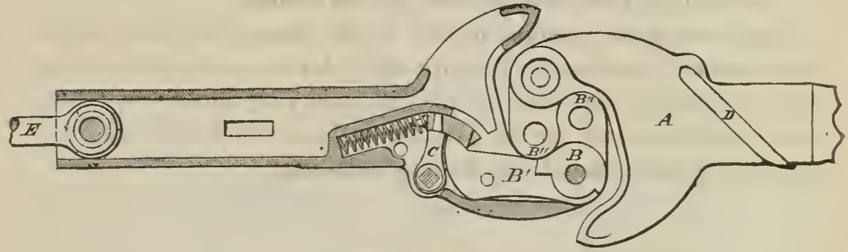
Fig. 5 represents a sectional and Fig. 6 an end view of same.

The knuckle, *B*, represents a pinion with two teeth, *B′* and *B″* (the other teeth of the series being dispensed with) and the drawhead, *A*, and tooth or nose, *B″*, of the other coupler representing the rack. When the couplers are forced together, the teeth engage each other, the hub revolves, and the long tooth, *B′* is carried around into a locking position; the catch, *C*, being forced back by the circular end of the tooth, *B′*, in passing, after which the catch is returned to its locking position by the catch-spring.

The action in coupling is similar to a pinion, being revolved by the rack, or, when both knuckles are thrown open, to two pinions passing each other and turning on their axes.

The uncoupling is effected by throwing over the platform lever, *M*, Fig. 6, which in turn forces around the coupler-lever, *D*, Fig. 2, and catch *C* back, so as to allow the tooth, *B′*, to revolve outward.

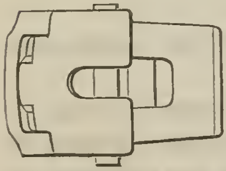
FIG. 2.



It will be observed that the two couplers, when united, form a perfect and closely-fitting knuckle-joint, and therefore give perfect freedom in curving, without either lateral or longitudinal lost motion. It will also be noticed that the guard-arms extend beyond the head of the opposite coupler, and thus absolutely prevent accidental uncoupling; while, from their shape, they serve to guide the parts into coupling position as they approach each other.

The buffers, *F*, Figs. 5 and 6, are attached at their rear ends to an equalizing bar, which makes the compression on each buffer-head, equal under all circumstances.

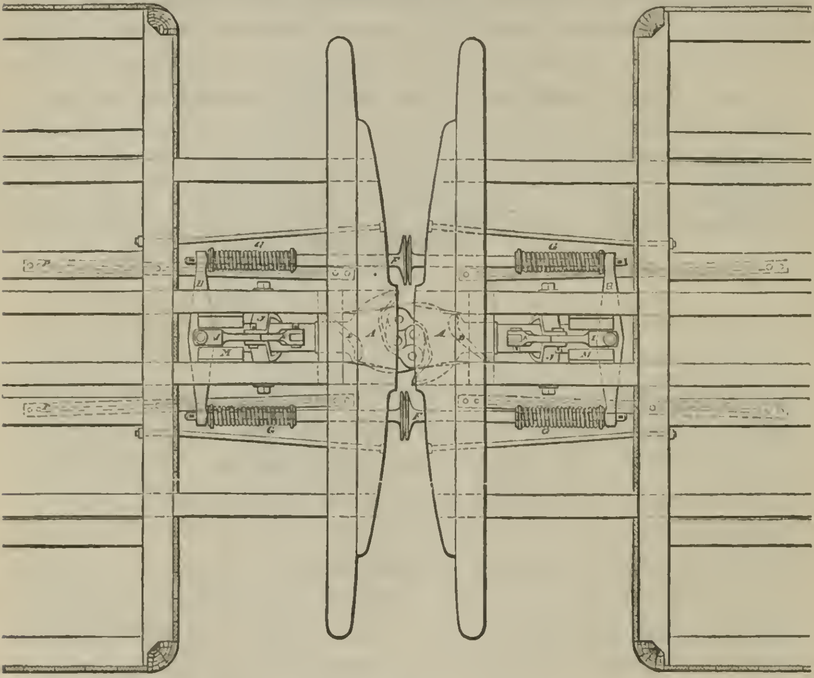
FIG. 3.



The equalizing-bar, *H*, is pivoted, at its centre, to the clevis, *I*, which in turn is pivoted to the yoke-lever, *J*, and the yoke-lever connected to the horn, *L*, by means of the clevis, *K*. The yoke-lever is pivoted midway between the pivot point of clevis *I*, and its point of contact with the lower end of horn *L*, below the coupler; hence its movement must be in the arc of a circle. It will be seen that the clevis, *I*, is pivoted at almost double the distance from the yoke-lever pivot point, as the clevis, *K*, and therefore, in a forward movement, would travel nearly twice the distance.

The object of this combination is to increase the compression on each buffer-head as the cars move from their normal position in either direction, and to keep them in close contact, under all circumstances, without the use of heavy buffer-springs, or extending the buffers out so far before a coupling is effected, both of which methods are objectionable, and do not accomplish the object sought. The operation is as follows:

Fig. 4.



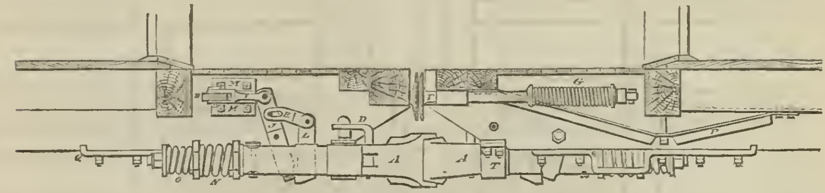
The buffer-heads stand out, before a coupling is effected, about 1 inch beyond the inside face of the coupler-knuckle, and have to be forced back that distance to make the coupling, which requires about 1000 lbs. pressure on each buffer-head.

When the train is started, the coupler-draft springs, *O* and *N*, yield, allowing the coupler to be drawn out, and with it, by means of the intermediate connection heretofore described, the equalizer, but at an increase motion over the coupler in proportion to the difference in the distance between the pivot points of clevises *I* and *K* from the pivot centre of the yoke-lever, which increase is provided for by the compression of the buffer-springs, *G*.

It will be understood, therefore, that if the compression at the start is equal to 1 inch, and the movement of the equalizer over the coupler is at the rate of nearly 2 to 1, when the coupler has traveled 2 ins., the equalizer will have traveled nearly 4 ins., thereby increasing the compression on the buffer-springs, *G*, 2 inches, making 3 inches in all.

The same is true in buffing, except that the increase is more rapid. The platforms being about $2\frac{1}{4}$ inches apart, there can only be a movement on the part of each of $1\frac{1}{8}$ inches before they touch. In this movement the buffers are forced back on the springs, *G*, to that extent which, in addition to the first inch gained in coupling up, makes $2\frac{1}{8}$ inches. While this movement is going on, however, the lower end of the horn, *L*, being firmly mortised into the coupler and moving with the same, has, by its contact with the yoke-lever, rocked the same on its pivot, throwing forward the equalizer $1\frac{1}{8}$ inches, thus producing in all about 3 inches compression by the time the platforms have touched. In addition to this resistance (the object of which is to prevent the butting of the platforms except in case of collision), the spring, *N*, which acts in the two-fold capacity of buffer and draft, is shortened, so as to limit its movement to $1\frac{1}{4}$ inches, and enable its full resisting power to be utilized in this movement.

Fig. 5.



To overcome the increased difficulty in starting trains, caused by shortening said spring, another and lighter spring, *O*, is added, which, when the draft is applied, yields first.

By this arrangement the inertia in starting heavy trains is much more easily overcome than by the ordinary 8 in. draft springs.

The brace, *C*, Fig. 5, is designed to sustain the platform, and is admirably adapted for this purpose.

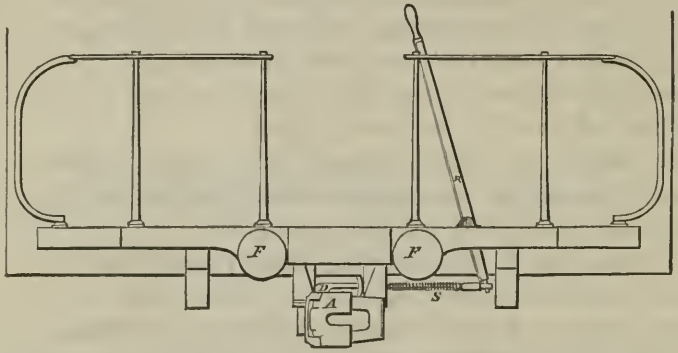
The construction of the intermediate mechanism is such that no amount of pressure upon the buffer-heads produces any counteraction on the draft-springs, *O* and *N*.

Some of the advantages of this improvement have been referred to in the foregoing description, but there are others which deserve special mention.

It is claimed for this device, that by its use telescoping is more effectually prevented than by the use of any other, and for the following reasons :

In addition to the platforms being elevated to a line with the sills of the car-bed, they are brought and kept in closer contact, making of the entire train one elastic structure. Besides, the couplers being closely interlocked, and acting constantly so as to sustain each other against lateral movement, the platforms are prevented from sliding by each other or buckling, as is the tendency in collisions. Practical demonstration has been had of this in several collisions that have occurred, and where no damage or injury was sustained.

Fig. 6.



Another advantage possessed by this improvement (the absence of which would have been fatal to its adoption by the roads now using it) is that under no circumstances, it is believed, can the train part accidentally. Experiments were made to test this fact, in the following manner. The two rails of the track were cut and elevated about 2 feet above the track level (triangular blocks of equal sides being used to aid the wheels in mounting and descending), and the train run back and forth over the obstruction a number of times, without parting or any injury resulting.

An accident occurred to a train of five cars running at the rate of fifty miles per hour, in which the truth of the foregoing was fully established. The middle car in the train, in passing a curve, was thrown from the track and toppled over to an angle of nearly 45°, and held by the coupler in this condition until the train could be stopped, when it was found that the body bolts and axle were bent, but this car with its fifty passengers, as well as the whole train, saved from complete destruction by this improvement, which was found still to be in perfect condition.

The reasons for this will be understood when it is noticed that the coupler of one car extends, and always remains, under the opposite platform, and *vice versa;* consequently, neither platform can fall below the coupler of the opposite car.

Still another advantage, is that by the peculiar construction of the coupler, being a closely-fitting joint and without longitudinal or lateral play, the unpleasant oscilation or swinging of the platforms in opposite directions is overcome, thereby adding greatly to the comfort as well as safety in running trains.

There can be no doubt whatever, that greater steadiness and smoothness, as well as more perfect security, is obtained by the use of this improvement, than has been heretofore.

Its adoption, as a whole, by the Pennsylvania Railroad for its main line and all the lines it operates or controls, and by the Pennsylvania Company for its immense system west of Pittsburg, after a thorough and exhaustive test covering a period of nearly four years, is sufficient of itself to indicate its importance and value.

SELF-LUMINOUS CLOCK DIALS.

By Henry Morton, Ph. D.,
President of the Stevens Institute of Technology.

My attention having been drawn to the "luminous clocks" which have recently been offered for sale in several places, I made an analysis of the substance with which their dials are coated, and found it to consist of nothing but the well-known phosphorescent compound, sulphide of calcium, attached by means of some resinous medium, like varnish.

But while the material in its composition is far from novel, something or other in its method of manufacture and consequent condition, gives it such intensity of properties as has never been approached before.

In the cabinet of the Stevens Institute are numerous specimens of phosphorescent powders (sulphides of calcium, barium, and strontium), which represent the best products heretofore obtained. These, if exposed to strong sunlight or to an electric discharge, or the like, will glow for many minutes in the dark.

One of these clocks, however, I found would continue to glow with sufficient brightness to be visible across a room all night, and could be read at any time if approached closely.

After being shut up in a box for five days, this clock was still visible in total darkness, when the eyes had been rendered sensitive by remaining in the dark for a few minutes.

This clock dial is also readily "excited" by lamplight or gaslight, or indeed by any source of light containing rays above the yellow of the spectrum.

The light from a Bunsen burner with soda in the flame, if filtered through yellow glass, will not excite it however, but if the yellow glass is omitted, the blue rays of the Bunsen burner flame will serve to excite the phosphorescence of this remarkable material.

The cause of this action is believed to be somewhat as follows: When light falls on certain bodies, its vibrations cause molecular changes which are not permanent, but are only maintained by the action of the "exciting" vibrations, somewhat as a mass of plastic substance can be kept in a soft condition by constant stirring. When the exciting cause is removed, the molecules return to their normal positions, and in so doing, set up vibrations which are the cause of light, very much as the solidifying of water evolves heat.

Thus these bodies, when exposed to daylight, absorb as it were the light energy, and re-emit the same afterwards.

The phosphorescent property of sulphide of calcium has been known since 1768, when Canton prepared it by heating together intensely for an hour, three parts of calcined oyster-shells, with one part of sulphur. Its properties in this relation have been elaborately studied by Becquerel, who published his researches in the *Annales de Chimie et de Physique*, and has also devoted a large part of the first volume of his book, "La Lumière," to this subject. He found that by employing lime in different forms, such as Iceland spar, marble, oyster-shells, aragonite, etc., products emitting different colors by phosphorescence, such as orange, yellow, green, blue and violet, were obtained.

The light given out by these clocks is a violet blue, like that which Becquerel produced with aragonite, but Becquerel makes no mention of anything whose duration of luminosity approaches that of these clock dials.

In making up some of these preparations, I have noticed that out of the same batch, some portions will glow by phosphorescence much more brightly than others, so that evidently this difference depends upon some very small structural or molecular variation, and there can be little doubt that it is by some method of securing a desirable condition of this sort, that the remarkable efficiency in these clock dials is attained.

If still further advances should be made in this direction, it is easy to imagine some very wonderful results, before which even Mr. Edison's new electric burner will fade into insignificance.

Thus, if our walls were painted with such a substance, they would absorb light enough during the day to continue luminous all night, and thus render *all* sources of artificial light useless, superseding even the new electric burners, no matter how little they might cost, for it would then only be necessary to provide curtains, which could be drawn over the walls, like shades over windows, when *darkness* was desired. The coloring of houses on the outside with a like material would also evidently obviate the need of all street-lamps.

I do not, like some of Mr. Edison's friends, in reference to his new electric burner, expect that this *still more remarkable and economical* source of light is certain very shortly to displace gas and all other sources of artificial illumination, but if conjectures are to be the order of the day, I do not see why this conjecture is not as good as many others which have been made.

Seriously, this new form of the phosphorescent sulphide of calcium, made of the cheap materials, sulphur and lime, is a truly wonderful substance, which may well suggest strange possibilities for the future.

Composition of Elements.—By reasoning from analogies furnished by the action of known compounds, Lockyer finds evidence that many of the supposed chemical elements are really compound. He has devoted three years' careful research to a comparison of chemical spectra with spectra of various heavenly bodies.—*Comptes Rendus.* C.

THE WATER-SUPPLY OF THE KINGDOM OF WÜRTEMBERG.

Although we live in a comparatively new country, where few streams are as yet seriously polluted by a dense population, or by manufacturing industries, we have already begun to feel the disadvantage of the individual action, with reference to water-supply and sewerage, of different towns in the same drainage-area or river-basin. The difficulties increase in proportion as a country becomes more densely populated, and it is easy to explain the great interest which has been excited in England by the congress lately held under the auspices of the Society of Arts, at the suggestion of H. R. H., the Prince of Wales, to consider the question of the "National Water-Supply."

It is true that the State legislatures exercise a general control over the establishment of water-works, but any one who has watched the passage of a bill through the legislature or the legislative committee, knows the variety of interests which determine the advocating or the opposing of such a scheme. It would be of great present advantage, if there were in each State some central authority charged with the general oversight of the available sources of water-supply. That something of the kind will eventually prove necessary, admits of little doubt. In this connection something may be learned from the experience of the Kingdom of Würtemberg,* which, as it has an area of about 7500 square miles, may be compared, as far as to size, with the State of Massachusetts.

In the year 1869, there was created, in the Kingdom of Würtemberg, a new office, that of "Staats-Techniker für öffentliche Wasserwerke." It was made the duty of the Staats-Techniker to superintend the planning and construction of all public works for the utilization of the available river and spring waters, and to advise, in matters of water-supply, the local authorities of any village, town or city within the kingdom,—this advice including the preparation of plans and estimates, and being without cost to the community asking the advice.

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* Das öffentliche Wasser-Versorgungswesen im Königreich Württemberg. Denkschrift aus Anlass der internationalen Ausstellung für Gesundheitspflege und Rettungswesen in Brüssel verfasst von Oberbaurath v. Ehmann. Stuttgart. 1876. 4to, pp. 137.

This work being printed for private distribution only, is not readily obtained. Abstracts are to be found in the Correspondenzblatt der niederrheinischen Vereins für öff. Gesundheitspflege, vi (1877), p. 99; and in Grahn's städtische Wasserversorgung, i, pp. 4-9.

The first to fill this office was the present incumbent, Dr. von Ehmann, an engineer of long practical experience, and well acquainted with the local conditions.

The extent to which the creation of such an office met a felt want, appears from the statistics which follow.

The number of communities availing themselves of the services of the Staats-Techniker with a view of introducing a system of water-supply, was as follows:

	Urban.	Rural.	Total.
During the year 1870,			70
" " " 1871–2,	33	61	94
" " " 1873,	13	19	32
" " " 1874,	15	26	41
" " " 1875,	16	40	56
			293

Previous to 1870, works had been constructed for supplying 45 communities with water, and up to January 1, 1876, there have been carried out, and brought into actual operation, 96 distinct works, in addition to those undertaken for supplying the so-called "*rauhe Alb*," to which allusion will presently be made; so that, during a period of ten years, 130 localities, or one-fourth of the entire number in the kingdom had been supplied with water.

The most interesting part of the work has been the supplying water for the "rauhe Alb." This district, which lies from 750 to 800 metres above the level of the sea, and some 300 metres above the surrounding low lands, has a width of some 33 kilometres, and is of such a geological character that the rain-fall quickly disappears in the clefts of the limestone or dolomitic rock, and does not appear again in springs within the region. The surface and rain-water collected by the inhabitants in cisterns and in puddled cavities in the ground, was not only inferior in quality, but so insufficient in quantity that often in cold or dry weather it was necessary to bring water from the valley below, a distance of from 2 to 12 kilometres.

The plans for supplying this district, containing between 60 and 70 villages, with some 40,000 inhabitants scattered over an area of 22 square miles, were devised by Dr. v. Ehmann, and, although at first there was some opposition, principally on account of the attendant expense, the plans were finally adopted, and have been already carried out to a considerable extent, generally with aid from the State.

The villages are divided into 9 groups, each group forming a unit for purposes of water-supply. The water is taken partly from natural springs in the lower land, and partly from the ground-water by means of wells and galleries, and is pumped by water-power to the plateau above.

The height to which the water has to be forced in order to reach the various distributing reservoirs, as well as other details, may be learned from the following table:—

Group.	No. of communities.	Total inhabitants.	Amt. of water in cubic metres per day.	Height to which water is lifted in metres.	Length of mains in metres.	Source of water.
I	9	7525	600	265	34,000	Springs.
II	8	7600	570	300	50,000	Ground-water.
III	8	3600	270	180–255	30,000	Ground-water.
IV	8	3700	280	117–200	32,000	Springs.
V	9	3800	280	320	50,000	?
VI	7	1700	130	180	28,000	Springs.
VII	9	2000	170	220–230	30,000	Springs.
VIII	6*	4300	300	200		
IX	4	2900	200	173–230	25,000	Springs.

Besides bearing the expense of the preliminary surveys, of the plans, and of the superintendence of the work, the State contributed in some cases 25 per cent. of the cost of construction, and the work had progressed so far, that, at the time of the last published report —the summer of 1876—five of the groups, comprising 34 villages, with 17,010 inhabitants, were provided with a supply of water amounting to 1232 cubic metres per day. The total length of pipe laid, up to that time, was 144,000 metres.

While the problem of supplying a district of such size with water, which must be raised vertically to a height of from 200 to 300 metres, and where the force-mains are from 3 to 10 kilometres in length, is an interesting one to engineers, the coöperative idea, by which the various villages and towns are treated as parts of one whole, is interesting to all who are engaged in matters of water-supply. W. R. N.

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* In this district a portion only of the villages, namely, three, were supplied with water.

Geological Relations of the Atmosphere.—T. Sterry Hunt has investigated the geological bearings of the hypothesis of a universal atmosphere, which was proposed by Sir William Grove, in 1843. He believes that the carbonic acid, which is included in the calcareous and dolomitic rocks, must have had an extra terrestrial origin, and that such an origin can be readily accounted for, by supposing that our atmosphere is part of a universal cosmical medium, which is condensed around centres of attraction in proportions depending on their masses and temperatures, and occupying all the interstellar spaces in a state of extreme rarefaction. Many considerations go to show that the atmospheric changes did not permit a glacial temperature at the sea-level until towards the end of the tertiary epoch. Matthieu Williams used the same hypothesis, in 1870, to account for solar heat, and Hunt employed it, in 1874, to explain the origin of nebulæ and the generation of elements by a cosmical chemistry, in accordance with the ideas of F. W. Clarke and Lockyer.—*Comptes Rendus.*

C.

Preservation of Iron.—Capt. Bourdon has devised simple forms of apparatus for coating iron with Barff's magnetic lacker. In the course of his experiments he found that the coat of oxide could be formed by the air, in the following manner; The serpentine part of a sheet-iron reservoir, communicates with air which is heated to 120° (248° F.). The current of hot air, after circulating through the serpentine, reaches the cylinder which contains the articles to be lackered. The escape-spout communicates with a water-aspirator regulating the flow of air, which should be very gentle. The internal pressure is little more than one atmosphere, the apparatus being in communication with the open air. The temperature of the air in the cylinders is 280° (536° F.); the operation lasts five hours, giving a coat five-hundredths of a millimetre thick (·002 in.), of a beautiful greenish black, resisting the action of fine emery-paper and of dilute sulphuric acid. After the articles are taken from the cylinder, they are rubbed with a greasy rag, and spots are removed by fine emery-paper or scouring-grass. Spots may generally be avoided by suspending the pieces, so that they will not touch each other or the walls. If the temperature is raised to about 300° (572° F.), a thick coat is secured, but it is apt to scale. Articles thus lackered have been exposed to snow and rain for a month without getting any spots of rust. If the black coating is removed by emery-paper, there is a grayish layer on which rust does not take much hold; the spots can easily be removed by a bit of hard wood. Barff has observed the same peculiarity in articles which have been steam-lackered.—*Ann. des P. et Chauss.* C.

Night-Temperatures at Different Altitudes.—It is often warmer upon mountains than in valleys, especially in severe winters. M. Alluard has found evidences, at the observatory of Puy-de-Dome, of frequent similar inversions at night, by tracing: 1. The curves of minimum temperature, in the two stations of the observatory. 2. The curves of maximum temperatures, obtained under the same circumstances. 3. The curves of the mean temperatures of the two stations, deduced from the maxima and minima. The curves of minimum temperature often intersect, in summer as well as in winter, so that the summit of the mountain is sometimes 5° (9° F.) warmer during the night than the base. There is no similar intersection in the curves of maximum temperature. The inversions occur most often when the upper and lower currents are from different quarters, but sometimes when the two currents have the same direction. Further observations are needed in order to find the cause of the anomaly.—*Comptes Rendus.* C.

New Lunar Crater.—Dr. H. J. Klein, in Cologne, has been watching the moon's surface with special care for about twelve years. Most of the investigations of the last century, by Schröter, Herschel, Mädler and others, have failed to discover any active volcano in the moon, so that the opinion has become general that our moon is a dead world, a burnt out and fossil heavenly body. This opinion must now be given up, since there is evidence of the present activity of powerful forces upon the moon's surface. Dr. Klein has discovered a crater near the centre of the visible hemisphere westward of Hyginus, in a broad level plain, appearing at the time of the first quarter as a dark shadowy gulf of about 4,000 metres (1·24 miles) diameter. Its inner surface exceeds all the present active craters of the earth, except that of Kilauea in Hawaii. Further observations which have been undertaken, especially in England and America, will doubtless show whether its activity still continues.—*Deutsche Rundschau.* C.

Periodic Movements of Flowers and Leaves.—The motions which have often been described, under the names of the *sleeping* and the *waking* of leaves or flowers, may be referred to a special point, at the base of the organ, which may be called the *motor tubercle.* The mechanism consists of modifications in the energy with which this tubercle supports the movable organ, an energy which is gradually restored during the night, and gradually exhausted during the day. P. Bert has shown that these facts may be explained by supposing the alternate formation and destruction, in the tubercle of some substance which has a great endosmotic power. Having accumulated in great quantity towards the end of the day, it absorbs the water which gives the nocturnal tension, while its gradual diminution during the day allows gravitation and other forces to require an ascendancy. This material is formed under the influence of the red and yellow rays of the solar spectrum, and is destroyed in darkness, or by the action of the blue-violet region; its collection, its formation and its absorption of water reduce the temperature of the motor tubercle, which is colder than the surrounding air and than the contiguous points of the stem. By a series of ingenious experiments and chemical analyses, Bert satisfied himself that the active absorbing ingredient is grape-sugar, which is prepared in the leaflets, under solar action, and accumulates towards night in the motor tubercle. The design of the movements seems to be, to reduce the evaporating surfaces to a minimum. Even the irritability of the sensitive plant is a protection against evaporation by the wind, which is the only agent that often disturbs the plant, when in its natural conditions. The common impression, that changes of evaporation play an important part in the movements, seems to be erroneous. If a sensitive plant is completely submerged, the spontaneous motions continue for about eight days; the only difference being that the sleep begins about an hour earlier and ends about an hour later than usual. The destruction of the grape-sugar goes on even during the day, under the direct influence of the luminous rays. This may be shown by placing a drop of common ink on the tubercle of a main petiole of a sensitive plant; the leaf immediately bends so as to show an increase of the subjacent energy. A drop of red ink produces no effect; but if a bit of India-ink is added, the petiole gradually moves, as the India-ink dissolves.—*Comptes Rendus.* C.

The Sun's Surface.—At one of the sessions of the French Association, Janssen described the apparatus which enabled him to take photographs with an exposure of $\frac{1}{100000}$ of a second, and explained the new information which such photographs have furnished respecting the upper surface of the photosphere. The polar regions are covered with a general granulation, of forms, dimensions and distribution very different from the ideas which have been derived from optical examination. Resemblances to willow-leaves, rice-grains, etc., may be occasionally traced in single points, but the prevailing and fundamental form is spherical, and the "grains" appear to be clouds of dust or mist floating in a gaseous medium. The luminous intensity of the sun resides chiefly in a few points, so that if the whole surface was as bright as the most brilliant portions, its luminosity would be increased from ten- to twenty-fold.—*La Nature.* C.

Curious Case of Heating.—M. Hirn reports some observations connected with the adjustment of the fly-wheel of a steam engine. In driving a large pin, one of the assistants rested against its head one end of a cylindrical iron bar about 1 metre (39·37 inches) long and 8 centimetres (3·15 inches) in diameter. Another workman drove the pin by striking upon the free end of the bar. The operation had hardly been begun, when the first man stated that at every blow he felt the bar grow very warm and suddenly cool again. M. Hirn, taking his place, found, to his great astonishment, that there was a great change of temperature, which he estimated at about 35° (63° F.). The hammer weighed about 5 kilogrammes (11 lbs.); the workmen lifted it about 2 metres (6·56 feet); supposing that the impulse of the arms added a velocity equivalent to a fall of 3 metres (9·84 feet), the increase should have been only 0·13° (0·23° F.), or only about $\frac{1}{230}$ of the observed effect. M. Hirn regards the phenomenon as subjective, and explains it as follows: "In order to observe the phenomenon it was necssary to stand very near the bar, with the head near the path of the hammer, and to seize the iron at about 1 centimetre ($\frac{2}{5}$ inch) from the end which was struck. This required firm faith in the skill of the workman who was wielding the hammer. I hesitated at first, and seized the bar at some distance from its end; nevertheless, I felt a strong sensation of heat, the source of which seemed to be in the interior of the hand, and not on the surface of the metal. When I became bold enough to take the proper position, the iron seemed to heat and cool rapidly at every blow, the sensation of heat continuing only as long as the sonorous vibrations which were excited in the bar by the blow. The best explanation of these facts, as it seems to me, is to suppose that under certain special circumstances sonorous vibrations, by agitating the sensitive nerves, excite a sensation of heat at the surface of the body analogous to the sensation of light which is produced in the eyes by a blow. This explanation, which I offer with some hesitation, may perhaps be tested by a Melloni thermometer, by observing whether a bar of iron, when struck at one end, really becomes heated during a short interval, so intensely as seemed to be the case in the experiment which I have just related."—*Comptes Rendus.* C.

Harmless Colors.—Brilliant colors are generally preferred for candies and children's toys; thus, for red and orange, vermilion and red lead are often used; for yellow, chromate of lead; for green, arseniate of copper or Scheele's green and Schweinfart green. For red, orange and intermediate hues, harmless colors have been hitherto unknown. M. Turpin has obtained, by combining oxide of zinc and cosine, red lacs, which resist the action of light and profitably replace the finest commercial vermilions. By adding chromate of zinc in varying proportions, these lacs yield lively colors, which may be used as substitutes for red lead and chrome yellows. With ultramarine, they furnish good violets. These products are unchangeable under the action of light or heat, and can therefore be incorporated in caoutchouc paste mixed with sulphur, oxide of zinc, etc., and exposed to the vulcanizing process without the least change of color.—*Bull. de la Soc. d'Encour.* C.

Utilization of Water-Power at Rock Island.—This improvement, intended to furnish water-power to the Government works, begun in 1867, is now complete.

It consists of a canal, 2000 feet long, 200 feet wide at the top, and 175 feet at the bottom, and involved the removal of 10,341,000 cubic feet of rock. There are two dams: the upper being 230 feet long and containing 418,250 feet of masonry; and the lower dam, 726 feet long and containing 168,000 feet of masonry. The supply of water is expected to be 20,000,000 feet per hour and to develop 2000 horse-power.

The power is transmitted by two shafts, 350 feet long, each driven by twenty water-wheels.—*Engineering News.* *

Strength of American Railway Cars.—On the 23d of October, 1878, a southeasterly gale prevailed in the Middle States, which was very severe at Philadelphia.

The anemometer of the Signal Service recorded a velocity of the wind of seventy-five miles an hour. Several steeples were blown down, and several hundred houses unroofed and otherwise seriously damaged.

Among the structures thus injured, was the depot of the Pennsylvania Railroad, West Philadelphia. It consisted principally of a main building, for waiting-rooms and offices, and two sheds, each 70 feet in width, and about 800 feet in length, extending northward from the main building, and on the side of the hill bounding the Schuylkill on the west. Immediately east of the depot, and about 25 feet below, are the tracks of the Junction Railroad. From its situation, the eastern shed was greatly exposed to an easterly storm. During the gale of October 23d, about 7 o'clock A. M., the shed was blown over upon several trains of cars, which were under it, ready to be dispatched.

So great was the strength of these cars, that they held up the wreck. The 10-inch cast-iron columns, 25 feet long, that supported the roof-girders, fell, in many cases, directly against the cars with the force due to their own weight and that of the whole roof, probably at least 6 tons to each column, impelled by the force of the wind added to that of gravity.

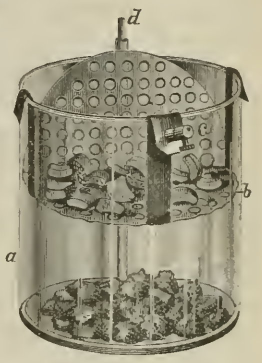
Notwithstanding this, not one of the cars was wrecked. In one instance, a column struck a car near the middle, and snapped off, but the framework of the car was not broken; the lower part of the column rested against the car—the upper part on its roof.

It has been frequently remarked that in railroad accidents in England, the fatality and wounding are greater than in the United States, owing to the fact that the English cars are not built to stand any extraordinary blow, and in the event of a collision or derailment, the cars are splintered to a greater extent than in this country; but it is so rare that a test like the above occurs, that we think it worthy of a permanent record.

A car that will stand, without injury, the impact of a 10-inch cast-iron column, with 6 tons of extra weight, driven by a gale of seventy-five miles an hour, contains an excess of strength that is very assuring to the traveler.

R.

Dr. S. M. Plush Battery Cell.—This battery cell is a modification of the Callaud battery, and consists of the glass jar, *a*, of the usual proportions, having at the bottom a copper plate upon which is placed sulphate of copper, and has attached to it the insulated wire, *d*, forming the positive pole. About half-way down the inside of the glass jar is the shelf, *b*, a perforated sheet of copper, upon which is placed pieces of zinc of any form. The shelf is suspended by three strips of copper, one of which, *c*, constitutes the negative pole. With this form of cell, the zinc of commerce can be broken into pieces of suitable size and used without any other preparation, and the zinc can all be consumed; while in the Callaud battery, the zinc must be cast into suitable form, involving some loss of metal and expense, and as a considerable percentage of the zinc of such castings is not consumed it must be re-melted at still further loss. Another advantage is that the sulphate of copper can be fed into the bottom of the cell through the opening left by turning up one side of the shelf, *b*, and broken zinc placed upon the shelf, without disturbing any of the connections, thus making the battery absolutely continuous. Objection has been urged that there will be local action between the zinc and the copper of the shelf, but Dr. Plush holds that practically no such action can take place, as there is really no closed circuit between the pieces of zinc and the copper. Lead may be substituted for copper in making the shelf, *b*.



Cost of Street Lighting by Electricity in Paris.—At a recent meeting of the Society of Arts, Mr. Jas. N. Shoolbred read a paper "On the Practical Application of Electricity to Lighting Purposes," giving the particulars of cost of plant and of operating electric lights under a variety of circumstances, and by several different systems.

Of the various streets and other places in Paris, lit up by the Jablochkoff system, the Avenue de l'Opera is the one which, from its central position, has attracted most attention, and therefore, will be taken here as a type example.

The Avenue de l'Opera, including the Place de l'Opera at one end, and the Place du Theatre Français, are lit up by 62 lights; 46 single-candle and eight double-candle (on the Place de l'Opera). Originally, only about 40 were provided, but the illumination being insufficient, the number was augmented (at the contractor's expense) to the amount just stated.

These are divided into four groups; one on the Place de l'Opera, two in the Avenue de l'Opera, and one on the Place du Theatre Français. Each group of lights is supplied with electricity from a (double) Gramme "16 light" machine, driven by an engine of 20 nominal h. p.

A very considerable amount of mystery has been kept up by the patentees of this system as to the cost of it. The expense they state it to be is (1·06 francs) 11*d.*, nearly, per light per hour, which they hope, so it is said, shortly to reduce by one-half. However, the payment to the patentees by the City of Paris is at a rate of 1·25 francs per hour on each of the original lights stipulated in the contract, the augmentation to 62 being entirely gratuitous by the contractor and in order to keep up an effective illumination. The total remuneration is 37·2 francs (29*s.* 9*d.*) per hour. The original gas illumination consisted of 344 jets, and costs 7·224 francs (6*s.*) per hour. The electric illumination is considered, however, as equal to 682 gas jets, say, to double the original illumination; that is, to a cost of 14·45 francs per hour, as against 37·2 francs for the electric one. The latter, therefore, cost 2·6 times that of the gas of equal illuminating intensity.

Need it be added that the City of Paris have terminated the contract with the last day of November.

The contractors have, however, offered to continue the contract at the reduced rate of 0·60 francs (6*d.*) per light per hour. The Municipal Council of Paris have declined to continue any contract, except provisionally, up to January 15th, 1879, and that only at the rate of the original cost of the gas, viz.: at a total expense of 7·224 francs (6*s.* nearly) per hour. By information lately received from Mons. Allard, the chief engineer of the lighting department of the City of Paris (under the engineer-in-chief, Mons. Alphand), and by whom the above details have been kindly communicated, the contractors for the lighting, the Societé Générale d'Electricité, have consented to undertake the lighting at the above reduced rate. The price paid to them, therefore, will be, up to January 15th next, at the highly remunerative rate of about 1⅛*d.* per light per hour.

A series of very careful photometric measurements carried out by the Municipal authorities in the Avenue de l'Opera itself with the existing illumination, showed each light to possess a maximum of 300 candles of intensity with the naked light; while by the interposition of the opaque globe, the maximum was reduced to 180 candles (a loss of 40 per cent.), and this again to a minimum of 90 candles during the darker periods through which this light passed.

Many other applications of the Jablochkoff candles with the Gramme machine occur in Paris, such as at the Magazins and the Hotel du Louvre, at the Theatre du Chatelet, at the Hippodrome, at the Hotel Continental, etc. Still, as in none of these cases have the financial results been ascertained on such good authority as in the case of the Avenue de l'Opera, it has been thought advisable to pass them over. The main object, held constantly in view in the present communication, has been to ascertain the carefully prepared financial results of a few applications, which have been supplied on unimpeachable authority, rather than to attempt to present those of a larger number, in some of which the results might have been open to doubt. *

Book Notices.

FORMULÆ FOR THE CALCULATION OF RAILROAD EXCAVATION AND EMBANKMENT, AND FOR FINDING THE AVERAGE HAUL. By John W. Davis, C. E. 8vo., pp. 106. Gilliss Bros., N. Y., 1877.

The second edition of a work, and the fact of it being adopted by the most important schools in a country, is sufficient endorsement of public favor to clearly demonstrate its merits.

The "average haul" has been added; a point of the highest interest to contractors and engineers. We feel sorry that the calculations of the same were not done without the assistance of "calculus," as the so-called "practical men" may be familiar with general mathematics, and not with its higher branches. Those who have these advantages, will be able to understand that the "average haul" is the distance between the centre of gravity of the material as found, to its centre of gravity as deposited; and also why, when monthly estimates are made, these correspond to the total of the smaller cross-sections, and would consequently be a proof that all previous work had been accurately executed. Those familiar with railroad excavation and embankment, know that this is not the case when the ordinary formulæ are adopted.

We can only say in conclusion that it is to be hoped that the adaptation of Mr. Davis's formulæ will give the exact volume corresponding to regular or irregular sections, and that it is to be greatly regretted that the various mathematical formulæ (that the engineer has at his disposal) for the calculation of earth work do not agree in their final results. W.

METALS AND THEIR CHIEF INDUSTRIAL APPLICATIONS. By C. R. Alder Wright, D. Sc., etc. 12mo, pp. 191. Macmillan & Co., London, 1878.

It is difficult to write on "Metals and their chief Industrial Applications," and show any great originality, as one has at his disposal many thousand examples and theories. Notwithstanding, the author has succeeded, in many cases, in explaining to his reader, in an intelligent and simple manner, several facts pertaining to metallurgy which appear complicated to beginners. He supposes, without a doubt, that we are all familiar with the principles of chemistry and the elements of physics—as it would be hardly possible to comprehend the various processes adopted for native metals, simple ores (oxides, chlorides, fluorides, etc., and also sulphides, carbonates)—nor could we realize the exact meaning of absorption or evolution of heat, nor the calculations pertaining to the value of caloric distubance when the reactions take place at a given temperature. The manufacture of pens, pins, looking-glasses, etc., being the examples chosen to illustrate the industrial applications of the above, have been most judicious, as the comprehension of these does not necessitate deep scientific knowledge, and represents objects with which the general reader is familiar.

We consider the title, *chief* industrial applications, not exact, as but the minor and simpler ones have been mentioned. This little work is written in a pleasing and modest style, and has not the pretension of being complete; but, on the contrary, is but an outline, where the general principles have been observed, a portion of the same being a course of lectures delivered at the Royal Institution of Great Britain, in 1877, by the author. W.

ELECTRIC LIGHTING. A partial treatise, from the French of Hippolyte Fontaine, by Paget Higgs, Assoc. Inst. C. E., etc. E. & F. N. Spon, London and New York, 1878. 8vo, 194 pp. Price, $3.00.

This translation supplies a place in English scientific literature, in giving the fullest information down to the most recent date, in plain, popular language, of the practical operation and mechanism of the electric light. The electrical, dynamic or physical theories, which, in their relations to the production of light or force by electricity, open fields of abstruse interest to the student, are left almost unconsidered, but here will be found, in words that any one can read and comprehend, what has been done to produce the electric light in various ways, what apparatus has been employed in so doing, fully illustrated by well executed wood-cuts, and clearly described in the well printed text. The historical portion is somewhat brief, and the earlier efforts have been left without so full description or illustration as would be wished in a more thorough study, but in Chapter IV the subject of dynamo machines is approached with much completeness, so that the references can be followed if any one desires: and the subsequent chapters, if they do give undue prominence to the machine and practice of M. Gramme, they also convey to the reader a complete view of the working of machines and of lights. In fact, the book is somewhat partisan in its appreciation of M. Gramme and his share in the invention of the dynamo-electric machine, but this advocacy may be admitted, and the work will still have the highest merit.

The relations of three explorers of this field of science may be stated. In 1852, Dr. Page, of Washington, made a machine for a motor on a railroad. This machine had many features in correspondence with the dynamo-electric machines of to-day, and had Dr. Page recognized the fact, and worked upon it, there is a strong probability that it would have been the immediate precursor of a system of dynamo-electric machines. In 1861 and 1864, Prof. Pacinotti, of Pisa, not only devised and constructed an electric motor, but, in the last named year, he described its application and usefulness as a means of producing electric force, in such words that any person could thus apply it. It was like a man's constructing a watch with a key, and giving a written description how to wind it so that it would go, and the watch should never run for want of winding. In 1869, M. Gramme produced his machine, "identical in principle" with that of M. Pacinotti (to use the words of M. Fontaine), and he at once proceeded to press and develop its capability.

* * * The reader is referred to the book under review for more complete information, and if he has any interest on the subject of electric lighting, he will assuredly find this work very interesting.

B.

Franklin Institute.

Hall of the Institute, Dec. 18th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 135 members and 31 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting there were 18 persons elected members of the Institute, and the following donations to the Library were reported:

Proceedings of the 12th, 14th to 16th, and 24th annual meetings of the Board of Supervising Inspectors of Steam Vessels. Washington. From the Board.

Circulars of Information of the Bureau of Education. No. 1, 1878. From the Commissioner of Education.

Annual reports of Trustees of the Metropolitan Museum of Art. New York. For 1872, 1873, 1875, 1876 and 1878.
From the Trustees of the Museum.

Reports of the supervising architect of Treasury Department. Washington. For 1876 and 1877.
From the Supervising Architect.

Report on cold rolled iron and steel, by R. H. Thurston. 1878.
From Jones & Laughlins, Pittsburg.

Reports of United States Light-House Board, 1873–75 inclusive.
From the Board.

Report of Chief Signal Officer of War Department.
From the Chief Signal Officer.

On proposed removal of Smith's Island, by L. M. Haupt.
From Engineers' Club, of Philad'a.

Bibliographical Contributions, by Justin Winsor. No. 1. Cambridge, 1878.

Reports of Department of Marine and Fisheries, Canada. For 1868, 1869, 1871, 1873, 1874 and 1877, and supplements 1 to 3 to report for 1874; and 1 to 4 to report for 1877.

From W. Smith, Deputy Minister of Marine, Department of Marine and Fisheries, Canada.

Mode of Combustion in the Blast Furnace Hearth, by J. A. Church. 1878. From the Author.

Short Memoirs on Meteorological Subjects, by C. Abbe.

Dissipation of Electricity in Gases, by D. Bobonlieff. From C. Abbe.

Specifications and drawings of patents, issued from the U. S. Patent Office, for June and July, 1878. Wash., 1878. From the Commissioner of Patents.

Transactions of the Royal Irish Academy. Vol. 25, November, 1875; Vol. 26, January, March, May and June, 1876.

Proceedings of the Royal Irish Academy. Vol. 10, 1870.

List of Council, Officers and Members, of the Royal Irish Academy. 1876.

Pharaoh's Daughter; a drama on the plan of the mystery and parable play, etc. London. 2 Vols., 1868 and 1874. From the Royal Irish Academy.

Meteorology of the North Atlantic, during August, 1873, by Henry Toynbee. London, 1878. 2 Vols. Text and Plates.

Statistical sketch of South Australia, by Josiah Boothby. London, 1876. From the Author.

Bulletins 10 and 12, of the United States National Museum, by David S. Jordan.

Bulletins No. 1, 2d Ser.; No. 3, Vol. 2; and Nos. 2 and 3, Vol. 4, of the United States Geological and Geographical Survey of Territories. Wash., 1875–76, and 1878.

First annual report of the United States Entomological Commission, for the year 1877, relating to the Rocky Mountain Locust. Wash., 1878.

Miscellaneous publications Nos. 9 and 10, of the United States Geological Survey of the Territories. Wash., 1877 and 1878.

First, second and third annual reports of the United States Geological Survey of the Territories, for 1867, 1868 and 1869. Wash., 1873.

Geological and Geographical Atlas of Colorado and portions of adjacent territory, by F. V. Hayden, U. S. Geologist in charge. 1877. From the Secretary of Department of the Interior.

Report of the Chief Engineer of Illinois and St. Louis Bridge Co. Oct., 1871. St. Louis. From the General Manager.

Reports of the Department of Marine and Fisheries, Canada, for 1872, 1875 and 1876; and supplements to reports, for years 1873, 1875, 1876. From Hon. Wm. Smith, Deputy Minister of Marine Department of Marine and Fisheries, Canada.

First to third, and fifth to seventh annual reports of the American Railway Master Mechanics' Association, 1868 to 1870, and 1872 to 1874. From the Secretary of the Association.

Twenty-sixth annual report of the Council of City of Manchester, on the working of the free public libraries, 1877–78. Manchester, 1878. From the Council.

Illustrated catalogue of Morris, Tasker & Co.'s Works, Philadelphia. 11th and 12th classes. From E. Hiltebrand.

Annual report upon the improvement of the South Pass of the Mississippi River, showing the condition of the works on June 30th, 1878. By M. R. Brown. From the War Department, Wash.

Annual report of the Secretary of War, for the year 1878. From the Secretary of War.

The Actuary also reported a resolution from the Board of Managers, asking the appointment of a committee to report upon certain questions in connection with completing the awards of medals recommended by the Committee on Science and the Arts.

The Secretary reported, from the Committee on Science and the Arts, a resolution looking to the same end, and also the recommendation of the award of the Scott Legacy Medal and Premium to D. K. Miller, for his padlock.

Prof. E. J. Houston gave a description of the system of dividing the electric light, devised by himself and Prof. E. Thomson, including a new form of induction apparatus,* and a vibrating lamp using reverse currents, the principle involved in which they think will solve the problem of producing small electric lights economically.

The Secretary's Report embraced the Janney car-coupler and platform;† Dr. S. M. Plush's battery cell:‡ Aldred & Spielman's horse-car rail; J. Reynolds & Son's shaking and cinder-grinding grate; Pike & Heath's hand-pump; and the Needham musical cabinet.

The President announced that in accordance with Section 7 of Article XIV of the By-Laws, nominations should be made at this meeting for a President, Secretary and Treasurer to serve one year, eight Managers and one Auditor to serve three years, and one Manager to serve two years, to fill a vacancy in the Board, to be voted for at the annual election, on the third Wednesday in January next; whereupon the following members were placed in nomination:

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* See page 40. † See page 46. ‡ See page 63.

For President, Wm. P. Tatham and J. E. Mitchell.

For Vice-President, J. E. Mitchell and Henry Cartwright.

For Secretary, J. B. Knight.

For Treasurer, Frederick Fraley.

For Managers, Elihu Thomson, Hector Orr, Cyrus Chambers, Jr., Thomas Shaw. Henry R. Heyl, G. M. Eldredge, J. G. Baker, John Hall, Henry Cartwright, Robert Briggs, Wm. Sellers, J. V. Merrick, Charles S. Heller, J. Smetherst, W. V. McKean, R. E. Rogers, Charles M. Cresson, Wm. H. Thorne, Henry Asbury.

For Auditor, Samuel Mason.

For Representative in Pennsylvania Museum and School of Industrial Art, J. B. Knight.

The President appointed the following members to act as tellers at the annual election, to be held on Jan. 15th, 1879: W. A. Rollin, W. L. Dubois, Wm. Taggart, John Canby, Geo. Gardom, Samuel Sartain, G. M. Sandgran, J. W. Nystrom, Chas. Bullock, J. J. Weaver, W. B. Cooper.

On motion of Mr. Close, it was

Resolved, That in balloting for Managers at the next annual election, those receiving the eight highest number of votes, shall be declared elected for three years, and the one receiving the next highest number of votes, shall be declared elected to fill the vacancy.

On motion of Mr. Heyl, it was

Resolved, That the Secretary be directed to have printed, a sufficient number of lists of nominations, to serve as ballots at the annual election, and also to send one such list to each member, with the notice of the next stated meeting.

On motion of Mr. Eldredge, it was

Resolved, That action on the resolutions from the Board of Managers and from the Committee on Science and the Arts relating to awards of medals, be postponed to the next stated meeting.

The following letter was read:

PHILADELPHIA, S. E. Cor. 5th and Walnut Sts.,
December 16*th*, 1878.

J. B. KNIGHT, ESQ.,
Secretary Franklin Institute.

Dear Sir:—I am having a design made for a new "John Scott Medal," more attractive and of more intrinsic value than that heretofore awarded; and as there are some applications now pending before the Board of Directors of City Trusts, and some already favorably acted upon, I am anxious to get the matter all completed at an early day.

I write to know whether you used any particular form of "Certificate of Award," to accompany the Medal and the twenty dollars, when the awards were made by your Institution, as I think it would be well to retain the old form as far as possible. If you did, would you kindly let me have a copy of it. Yours, truly,

CHARLES H. T. COLLIS,
Chm. Com. on Minor Trusts.

Mr. W. P. Tatham, through the Secretary, offered the following preamble and resolutions, which were unanimously adopted:

WHEREAS, By a letter from the Chairman of the Committee on Minor Trusts, to the Secretary of the Franklin Institute, the Institute is informed that the said Committee are proceeding to distribute the Scott Legacy Premiums and Medals, which have heretofore been awarded by the Franklin Institute;

Resolved, That the Committee on Science and the Arts, and the Board of Managers, be directed to suspend all examinations and proceedings looking to such awards.

Resolved, That the Secretary be directed to reply to the Chairman of the Committee on Minor Trusts, that, as the awards of the Scott Legacy Medals and Premiums heretofore made by the Franklin Institute, have been made only after a careful examination by a committee of experts, a copy of whose report always accompanies the Medal, they have used "no particular form of Certificate of Award;" and in reply to that portion of his letter expressing a desire to "retain the old form" while changing the substance, to say that as the value of a medal depends upon the care and discrimination exercised in awarding it, there would be manifest injustice to those persons to whom the Committee of the Franklin Institute have awarded Medals inscribed "to the most worthy," and whose inventions have stood the test of an intelligent investigation, to use the same forms for awards made on different principles.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*

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The Franklin Institute is not responsible, as a body, for the statements and opinions advanced by contributors to the Journal.

MACHINES FOR MAKING ICE, USING SULPHUROUS ACID OR AMMONIA IN THE PROCESS.

Note from the Establishment of Raoul Pictet & Co., Paris.

Translated by Robt. Briggs, C. E.*

The result accomplished by a machine in making ice and its corresponding expenditure of force can be investigated as follows:

In order to ascertain with exactness the useful effect of a freezing machine it is needful first to establish the theoretic maximum effect which it can produce, and then make a comparison of ideal result with what may be derived in practice.

[The difference between the theoretic and experimental results will represent the losses incident to the mechanisms employed and to the process followed; being in one case loss of power from friction of parts or of heat from radiation from the apparatus, and in the other the heat expended and transmitted over and above that absolutely demanded for mechanical effect or required to be removed for refrigeration. These losses are grouped in the original under the appellation of "passive efforts."]

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* The paragraphs in [brackets] are amendments or additions to the original.

1st. When making ice by any process whatever, it is indispensable to take up the quantity of heat which is set free by the congelation of water, and to carry that quantity of heat to water having the temperature of the surrounding air, which temperature is always above the point of freezing, and generally varies between + 10° and + 30° centigrade.

[Throughout this translation metric values for temperatures and quantities of all kinds will be used.]

2d. The mechanical theory of heat furnishes a general formula, which expresses the maximum of labor to be expended in obtaining this result. Calling q = a certain quantity of heat which is made to pass from the lower temperature = t to a higher one = t', and calling J = the mechanical equivalent of heat, equal to 431 kilogram-metres, we have:

$$q \frac{t'-t}{274° + t} J = \text{labor necessary.}$$

[This formula may be elucidated in the following way. The physical phenomenon on which all the machines for ice making is based is the relation of the sensible heat of gaseous bodies to their densities. A gas, having a sensible temperature below the freezing point of water, is permitted to take up a certain quantity of heat of refrigeration of water. It is then compressed by mechanical force until it shall have attained some given temperature above that of a water supply at the disposal of the apparatus, the water from which shall now take up and carry off the quantity of heat originally imparted to the gas, when the gas being permitted to expand (and in a perfect apparatus to give out its force of expansion to the machine) to its original density, it will be prepared to receive another charge of heat, and the complete cycle of operation will have been established.

Let Q be the quantity of heat present in a definite volume of the transfer medium—the gas—at the time when it is in condition to absorb the heat of congelation; let q be the quantity of heat imparted to the transfer medium by the congelation; then $Q + q$ = quantity of heat in transfer medium at some definite condition of energy, and sensible temperature = t which is to be elevated by mechanical effort to t' for the purpose of allowing q to pass off. Let the weight of the medium employed = W; then W, multiplied by the absolute temperature of the medium, at any sensible temperature whatever, represents the quantity of heat present at that temperature.

$$\therefore \quad W \times (274° + t) = Q + q \text{ at the temperature } t. \qquad (1)$$

$$W \times (274° + t') = Q + q + H \quad \text{“} \quad t'. \qquad (2)$$

where H = the increment of heat in passing from t to t'.

$$\therefore \quad H = W[(274° + t') - (274° + t)] = W(t' - t)$$

and as from (1) $W=\frac{Q+q}{274^\circ+t}$ $\therefore$ $H=\frac{(Q+q)\,(t'-t)}{274^\circ+t}$

Now, if the transferring medium parts with the quantity of heat q at the temperature $=t'$, and then is permitted to expand to its primary condition, and is made to give back by its expansion, the force of expansion, which is applied to the retrograding piston of the air or vapor pump, it will, when it reaches the first temperture $=t$, have given out force represented in heat units by $H'=\frac{Q+(t'-t)}{274^\circ+t}$ and the difference between the number of heat units expended in compression and those developed by expansion $=H-H'=\frac{Q+q\,(t'-t)}{274^\circ+t}-\frac{Q(t'-t)}{274^\circ+t}$ $=q\frac{(t'-t)}{274^\circ+t'}$, representing the units expended in the cycle of work.

Whatever mechanical effort may have been expended in the act of transfer of heat from the water to the medium, during the congelation in its certain time, will be compensated for, in the transfer which occurs from the medium to the water for removal of heat, at the higher point of temperature. The same quantity of heat $=q$ having to be taken up and given out in constantly recurring intervals of time—practically in the same times.

Multiplying the heat units by the mechanical equivalent $=J$, we have Pictet's formula: $q\frac{t'-t}{274^\circ+t}J=$ mechanical effort.]

Suppose we would make 100 kilos. of ice per hour with water of 20°. Each kilo. of ice in such case will represent 79+20=99 calories. In order to estimate the force in horse-power, replace the letters by the following figures:

First, on the supposition of complete and instantaneous transfer of heat $t=0^\circ$ temperature of congelation.

$t'=20^\circ$ temperature of water of supply both for congelation, and for removal of surplus heat.

$J=431$ kilogram-metres = mechanical equivalent of heat.

One horse-power = 270,000 kilogram-metres per hour.

$$\therefore\ 100\times 99\times\frac{20^\circ-0^\circ}{274^\circ+0^\circ}\times 431\div 270{,}000=1{\cdot}154 \text{ horse-power.}$$

Second, for the machine with sulphurous acid there must be 10° difference of temperature at both extremes of the process between the water used, for congelation on the one hand, or for removal of excess of heat on the other, when

$t = -10°$ temperature transferring medium when vaporizing.
$t° + 10° = t' = 30°$ " " " to be condensed.
other values being as before (when $t°$ = temperature of water = 20°).

$$\therefore \quad 100 \times 99 \times \frac{30° - (-10°)}{274° + (-10°)} \times 431 \div 270{,}000 = 2{\cdot}4 \text{ horse-power.}$$

With the water at 10° $\therefore t = -10°$; $t' = 20°$, and each kilo. of ice representing 79 + 10 = 89 calories.

$$\therefore \quad 100 \times 89 \times \frac{20° - (-10°)}{274° + (-10°)} \times 431 \div 270{,}000 = 1{\cdot}618 \text{ horse-power.}$$

[The following table gives several numerical values to be applied in the formation of a scale which will exhibit graphically all the results from the formula:

TABLE OF COMPUTATION OF THEORETIC FORCE, in horse-power, demanded in making ice from water of various temperatures, on the supposition that the transfer medium be brought to 10° below the point of congelation for its lower temperature, and be carried to 10° above the water for removal of heat for its higher temperature, in order to effect the operation in a given time and against losses of heat.

Degrees Fahr.	Temperature of the water. } = $t°$	Latent & sensible heat to be removed. } = $79° + t°$	Range of temperature to effect removal. = $t' + 10°$ = $t° + 20°$	Absolute heat removed. = $\frac{t' + 10°}{264°}$	Theor'c horse-power demanded for 100 kilos. per hour. = x	Computed horse-power, } = $x + 20$ per ct. x.
	Degrees.	Degrees.	Degrees.			
14	−10	69	10	0·0379	0·418	0·502
23	−5	74	15	0·0568	0·672	0·806
32	0	79	20	0·0758	0·958	1·150
41	5	84	25	0·0947	1·273	1·528
50	10	89	30	0·1136	1·618	1·942
59	15	94	35	0·1325	1·993	2·392
68	20	99	40	0·1515	2·400	2·880
77	25	104	45	0·1704	2·835	3·402
86	30	109	50	0·1894	3·303	3·961
95	35	114	55	0·2083	3·800	4·560
104	40	119	60	0·2273	4·328	5·194

$$\text{Formula}: x = (L + t^\circ)\,\frac{\dfrac{q\,(t' - t)}{274^\circ + t}}{270{,}000} \times J$$

where L = latent heat of congelation = 79° ; q = quantity of ice per hour = 100 kilos ; t° = temperature of water, variable ; $t = 10^\circ$ below point of freezing $= -10^\circ$; $t' = t^\circ + 10^\circ$, variable ; J = equivalent of heat = 431 calories.

$$\therefore \quad x = (79^\circ + t') \times \left(\frac{t' - (-10^\circ)}{264^\circ}\right) \times \left(\frac{100 \times 431}{270{,}000}\right)$$

$$= 0{\cdot}16 \times (79 + t') \times \left(\frac{t' + 10}{264}\right).$$

Referring to the plate accompanying this paper, the line A represents the theoretic results of a machine using sulphurous acid. The abscissæ are the temperatures and the ordinates the corresponding forces in horse-power.]

3d. These results can be compared with the performance of the ice machine in the present Exhibition at Paris, the dimensions of which are as follows:

Stroke of piston or steam cylinder = 1 metre.
Diameter of " " = 50 centimetres.
Pressure of steam = 5 kilos.* per sq. centimetre.
Point of cut off of steam in cylinder = 10 centimetres.
Back pressure in steam cylinder = 0.15 kilos. per sq. centimetre.
Stroke of piston in cylinder for compression of sulphurous acid = 1 metre.
Diameter of cylinder for compression of sulphurous acid = 42 centimetres.
P = pressure at the time of expiration, 0·8 kilos. per sq. centimetre.
P'' = " " compression, 2·7 kilos. "
Velocity, 30 to 32 turns per minute.

In "Claudel's formulas," will be found (¶s 356—372, of Ed. 1857), for calculating the dimensions of condensing steam engines having a single cylinder with cut off, the formula for estimating the power given out is:

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[*] A kilogramme to the square centimetre = 14·22 lbs. to the square inch. An atmosphere = 14·7 lbs. per square inch, or 1·033 kilos per square centimetre. The horse-power, metrical value = 75 kilogram-metres per second = 270,000 kilogram-metres per hour = 1,052,971 lbs., in place of 1,980,000 lbs., the English value.

$$T_m = Vhk\left(1 + \log.\left(\frac{z}{z_0}\right) \times 2{\cdot}3026 - \frac{h'}{h} + \frac{z}{z_0}\right)$$

In this formula T_m = power given out in great dynamic units = 1,000 kilogram-metres—substituting for these their value in horse-power per second, we have

$$0{\cdot}075\,x = Vhk\left(1 + \log.\left(\frac{z}{z_0}\right) \times 2{\cdot}3026 - \frac{h'}{h} \times \frac{z}{z_0}\right)$$

which is the formula used in the original of this translation.

Where x = power given out in horse-power,
V = volume of steam per second of time, before cutting off, that is used under the full pressure h,
h = pressure of steam in metres of height of water = kilos. per sq. centimetre,
h' = back pressure in cylinder,
z = whole length of stroke in metres,
z_0 = length of stroke to point of cut off in metres,
Vh = labor done before cutting off,
$Vh \log.\left(\frac{z}{z_0}\right) \times 2{\cdot}3026$ = labor done after cutting off.
k = co-efficient dependent upon resistance of engine, taken by M. Pictet at 0·73.*

substituting in the equations the values given, we have (taking the velocity at 30 turns per minute, or one stroke per second)—

$$0{\cdot}075\,x = \left[(0{\cdot}5^2) \times \frac{\pi}{4} \times 0{\cdot}1 \times 5 \times 0{\cdot}73 \left(1 + \log.\frac{1}{0{\cdot}1} \times 2{\cdot}3026 - \frac{0{\cdot}15}{5} \times \frac{1}{0{\cdot}1}\right)\right]$$

$$0{\cdot}075\,x = [0{\cdot}196 \times 5 \times 0{\cdot}73(1 + 1 \times 2{\cdot}3026 - 0{\cdot}03 \times 10)]$$

$$0{\cdot}075\,x = 0{\cdot}7154(3{\cdot}3026 - 0{\cdot}30) = 2{\cdot}14807$$

$$x = 2{\cdot}87 \text{ effective horse-power.}$$

---

* This value of 0·73 does not correspond to any value given by Claudel (edition 1857), where k has given many values, dependent on point of cut off, from 0·72 for $\frac{1}{3}$d to 0.84 for $\frac{1}{8}$th; and also other values dependent on the size of engine, thus for several sizes of engines, all of which are supposed to cut off at one-fourth the stroke, the values given are from 0·44 for 4 to 6 horse-power to 0·74 for 60 to 100 horse-power. The co-efficient is purely empirical, and the value of the result in useful effect, derived from the computation, is not very satisfactory when it is considered that indicator cards could have been taken from the engine at the Exposition at any time.

[In the original, at this place there follows a computation of the force of compressing the gas in the compressing cylinder from 0·8 kilos. to 2·7 kilos pressure. It is impossible to accept this computation as the tension of vapor of sulphurous acid corresponding to 30°, the supposed maximum reached, or rather point of removal of heat, is 4·56 atmos. (= kilos. nearly), and the tension corresponding to 20°, the accepted temperature of the water, is 3·24 atmos. Probably the pressure P' was 3·7 kilos, but this value, used in the formula taken by M. Pictet & Co., gives a greater result in horse-power in the compression than was exerted in the steam cylinder. Indicator cards, with temperatures by observation, alone are reliable as practical data, and these are wanting to the above statements.]

The calculation of the weight of sulphurous acid evaporated at each stroke of the piston is as follows:

$$\text{Density of sulphurous acid} = 2{\cdot}21$$

$$\text{Weight per cubic litre, at } 0°, = 2{\cdot}88 \text{ grams.}$$

$$\therefore \text{Weight} = W = \pi\, r^2 \times 1^{\text{m}} \times \frac{274}{274+t} \times 2{\cdot}88 \times 1000 \times 0{\cdot}8\,;\ \text{taking } t = 0°$$

$$W = 0{\cdot}1385 \times 2{\cdot}88 \times 1000 \times 0{\cdot}8 = 319 \text{ grams.}$$

The useful effect of the compression being 90 per cent. between the limits of pressure named, this weight is reduced to 287 grams per stroke or half revolution of the engine.

The latent heat of evaporation of sulphurous acid is 94·5 calories per kilogram vaporized. The weight of ice formed per hour, independent of external losses by radiation or conduction, is:

$$\frac{287 \times 60 \times 60 \times 94{\cdot}5}{99} = 1{,}000 \text{ kilograms [977 exact result.]}$$

This machine makes 1,000 kilos of ice per hour, and employs 29 horse-power, of which only 22 is utilized in the labor of compressing the vapor of the sulphurous acid.

4th. In the plate, the curve C shows the maximum tension of the vapor of sulphurous acid at the temperature given by the abcissa, as ascertained by M. Regnault. [In the original paper it reads, "The temperature corresponding to 2·7 kilos 'effective' is 25°." This allusion would confirm the view of the translator that the pressure obtained in the compressor cylinder is 3·7 kilos. at least, but this rendering is fatal to the computation of power in the compressor as it appears in the original.

5th. If the value of power expended which has been computed from the formula of Claudel on the data given by M. Pictet & Co. be accepted as giving a correct result in the one particular instance to compare with that derived from the theory of heat, the simple addition of 20 per cent. to any of the theoretic values will exhibit with much fairness the practical useful effect. Some economies may attach to the performance of the larger apparatus, but those may be held to belong to the sizes of apparatus rather than to the resistance to be overcome. The line *B* shows the horse-power deemed requisite by M. Pictet & Co. to make 100 kilos of ice per hour. But the translator is of opinion that these values are about 25 per cent. too small, or, in other words, that the best practical result will be about 50 per cent. above the theoretic one, as there is not only to be met "the work expended in friction of connecting rods, cranks, pistons, screws, centrifugal pumps, etc.", but also many considerable and quite unavoidable losses of heat.]

6th. It is obvious that the same methods of reasoning and the same calculations will apply to higher or intermediate temperatures.

7th. [The final result from these considerations indicates a theoretic expenditure of force in making 100 kilos. of ice, per hour, by means of ice machines using sulphurous acid, to be from 1·27 to 4·3 horse-power, in countries having the extremes of temperature of 5° to 40°, and, according to M. Pictet & Co., from 1·53 to 5·2 horse-power, or, yet again, for liberal allowance, from 1·9 to 6·5 horse-power in countries having the same relations in temperature.

8th. Using a condensing engine, the consumption of coal per horse-power and per hour can easily be brought to 1·5 kilo. An engine cutting off its steam at 1-10th the stroke, as assumed in this case, with boilers of average economy, say the burning of 9 kilos of coal to the kilo. of water evaporated, = to the production of 4,833 calories, should develop a horse-power with under one kilo of coal per hour. This assumption of a large value for the coal per horse-power is confirmatory to the expenditure of more power than was apparently given out by the computation. Taking the translator's estimate for horse-power demanded, and the assumption of engines and boilers with one kilo. of coal per horse-power per hour, we have, in countries where or when water at 5° is attainable, about 50 kilos. of ice to 1 kilo. of coal, while in the hottest supposable locality, where the water reaches 40°, 16 kilos. of ice can be made with 1 kilo. of coal burned. Accepting 30° as the temperature of water in a hot country, 100 kilos. of ice ought to proceed from the expenditure of 5 horse-power, and 20 kilos. of ice from the combustion of 1 kilo. of coal. The assumption of engines to cut off at one-tenth the stroke is, however, not generally admissible for any but the largest engines, and the allowance of 1·5 kilo. of coal per horse-power gives 13·3 kilos. of ice to each kilo. of coal burned, as a high practical result.]

9th. The use of water power will considerably reduce the cost of running an ice machine.

[It may be remarked, as a final result of the foregoing, that the economy of ice machines evidently depends, 1st, upon the small differences of temperature between the transfer medium above the cooling water, on the one hand, or below freezing point of water on the other. In the case where fluids are used which condense at temperatures and pressure within the range of the operation, it is possible that much heat may be given out to the cooling water above the point of condensation and a non-reversable cycle be set up; and the economy depends, 2d, on the economy of the source of motive power, that is, of the steam engine and boilers employed.]

ICE MACHINES USING AMMONIA.

10th. In considering this class of ice machines, it will be assumed that their construction and process in operation is known. The quantity of heat to be furnished to the boiler is composed of two entirely distinct parts, the first of which is that necessary to evaporate the ammonia in the freezer, utilizing the latent heat, while the second is the heat lost by escape of temperature through the transmission of the total amount of heat which has to traverse five heavy iron apparatus successively. This loss will be estimated at its maximum theoretic value.

11th. Taking for calculation the production of 100 kilos of ice between ordinary limits of temperature in warm countries, that is to say, condensation at +30° and freezing at —30°, we have for the first source of expenditure of heat the loss, between a temperature of +140° [corresponding to 16 atmospheres pressures] and —30°, which are the extremes of temperature between which the non-reversible cycle of operations is performed, = (taking the water at 20°)

$$9{,}900 \times \frac{140-(-30^\circ)}{274+(-30^\circ)}=6900 \text{ calories.}$$

12th. And for second source of expenditure of heat—that of heat generated in the boiler, which is never returned, but is wasted in the process—we estimate the pressure in the boiler to be 16 atmospheres, which pressure shall be divided into:

4 atmospheres for steam,
12 " for the ammonia.

The distillations will occur proportionately to their maximum tensions, and then to remove 10,000 calories per hour [9,900, if the water to be frozen is at 20°] there should be evaporated 10 kilos. of water and 31 kilos. of ammonia.

We have then to adjust these two quantities of heat in order to find the minimum amount to be furnished by the boiler. [The total heat of water vaporized at +140° = 656 calories.]

The total heat of ammonia at +140° is 465 calories.

But the temperature of ammoniacal liquor with which the boiler is fed is 90°, which will reduce these figures to

566 calories for the water,
and to 411 " for the ammonia.

10 kilos. of water, at 566° = 5,660
31 " of ammonia, at 411° = 12,740 to which is to be added the theoretic loss as before computed = 6,900

25,300

There should be furnished 25,300 calories to the boiler as the least quantity to produce 100 kilos. of ice.

14. * * * [Supposing the consumption of fuel under the boiler is effected with average economy, as previously assumed, of = 9 kilos of water evaporated (4,833 calories) per kilo. of coal burned, we have:

$\frac{25{,}300}{4{,}833} = 5{\cdot}235$ kilos. of coal to the 100 lbs. of ice per hour, as the theoretic result without loss of heat in any way during the process. This result does not fairly represent the argument of M. Pictet & Co. The heat should be divided into two parts, as in the estimate. Of which $5{,}660 + 12{,}740 = 18{,}400$ calories will proceed from application of heat of fuel to the boiler, when $\frac{18{,}400}{4{,}833} = 3{\cdot}8$ kilos of coal may be assumed to supply this heat. And the 6,900 calories which will have been expended in transferring 9,900 calories through a range of 170°, by exertion of mechanical force, may be taken (having been derived through the action of a steam engine and pump) to have been effected as economically as was assumed in the sulphurous acid process. In the sulphurous acid process, with water at 20°, we have the heat of transferring the heat of congelation $= 9{,}900 \times \frac{30° - (-10°)}{274° + (-10°)} = 1{,}500$ calories, and our previous estimate gives 2·4 horse-power as the theoretic force accompanying the same. When $\frac{6{,}900}{1{,}500} 2{\cdot}4 = 11{\cdot}04$ horse-power, which may be taken at 1·5 kilo. of coal per horse-power, as before (¶ 8th).

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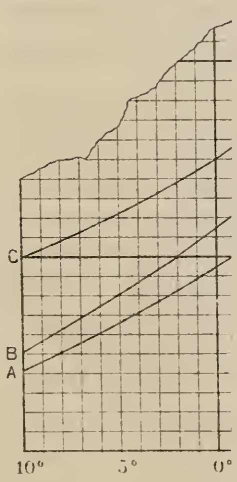

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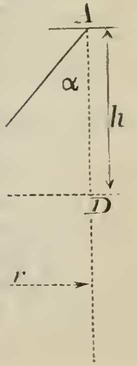

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CURVES OF USEFUL EFFECT, Etc.

OF

ICE MACHINES USING SULPHUROUS ACIDS.

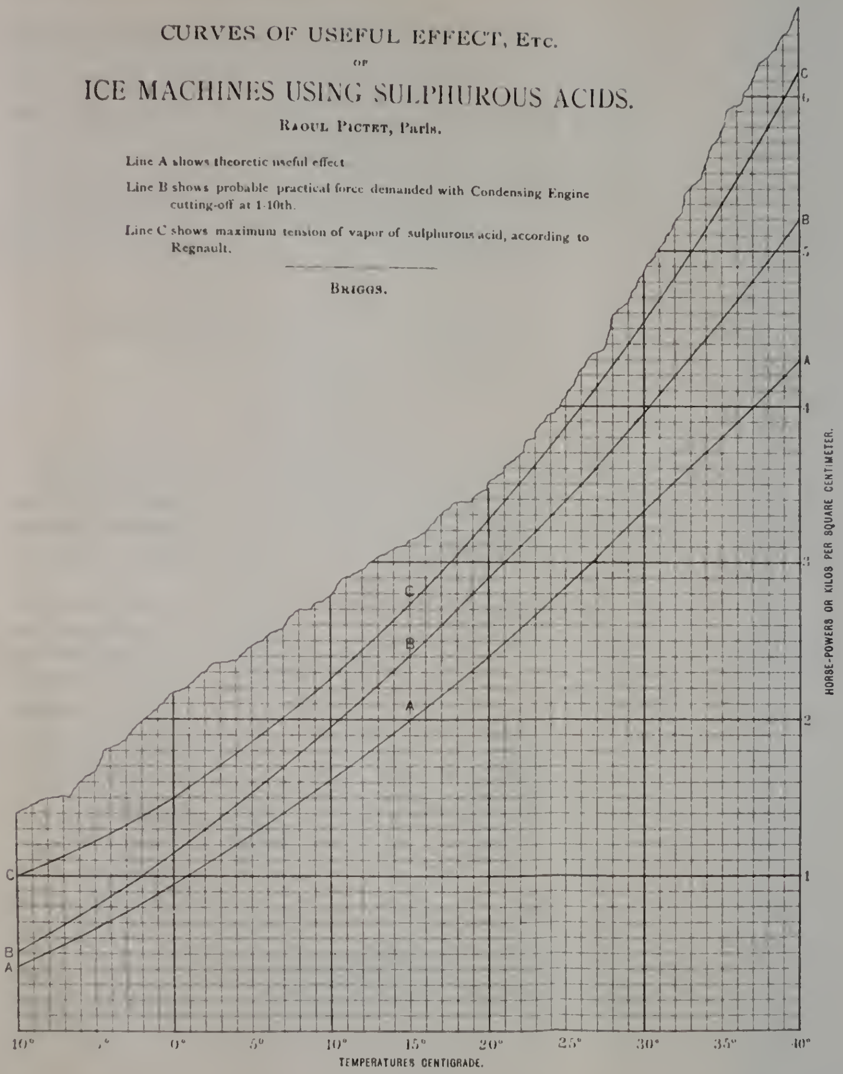
RAOUL PICTET, Paris.

Line A shows theoretic useful effect

Line B shows probable practical force demanded with Condensing Engine cutting-off at 1-10th.

Line C shows maximum tension of vapor of sulphurous acid, according to Regnault.

BRIGGS.



The theoretic quantity of coal consumed by the ammonia process then becomes $3·8+16·75=20·37$ kilos. (against the 3·6 kilos. by the sulphurous acid process.

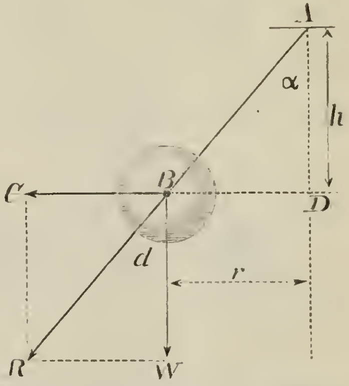
14A. It is noted in the original that the above estimate does not include the power for driving the feed pump or for agitating the liquid, and there is estimated at least 1·5 kilos. for these purposes and for the force expended in the transmission, and reference is made to lines of theoretic and practical effect of ammonia ice-making machines which do not seem founded on any reliable data or experimental basis. This portion of the paper would be more satisfactorily presented if it had the authorization of the maker of the Carré machine.]

STEAM ENGINE GOVERNORS.

By J. Haug, M. E.

The application of the conical pendulum as a governor to the steam engine dates from the time of Watt, and although countless modifications of this principle have been patented since that time, and certain advantages claimed for each of these, yet the general opinion of engineers conversant with this subject is, that only few of them can really be considered superior to Watt's, while, as regards simplicity, the latter has decidedly the advantage.

Fig. 1.



The two forces acting in a conical pendulum are:

The weight of the ball (W in Fig. 1) acting vertically downward, and the centrifugal force C, acting horizontally outward. Constructing a parallelogram of forces, the resultant R will give the angle α', at which equilibrium is attained. Then as angle α is equal to α', and the triangles $A\ B\ D$ and $B\ R\ W$ are similar, it follows that their respective sides are of the same proportion, or

$$\frac{h}{r} = \frac{W}{C} \qquad (1)$$

i. e., the height of suspension is to the radius of revolution as the weight of the ball is to its centrifugal force.

But the latter is:

$$C = \frac{(2\pi n)^2 r W}{g}$$

where n = number of revolutions per second and g = unit of gravity = 32·166 feet.

Introducing this term in Formula (1), we have

$$h = \frac{W g r}{(2\pi n)^2 W r} = \frac{g}{4\pi^2 n^2} = \frac{0{\cdot}81452}{n^2} \text{ in feet.}$$

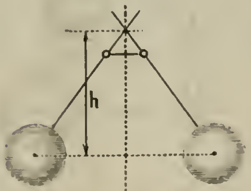
or if n_1 = number of revolutions per minute,

$$h = \frac{2993}{n_1^2} \text{ in feet.} \qquad (2)$$

and

$$n_1 = \sqrt{\frac{2933}{h}} \qquad (3)$$

Fig. 2.



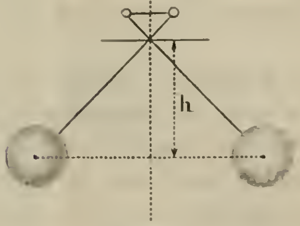
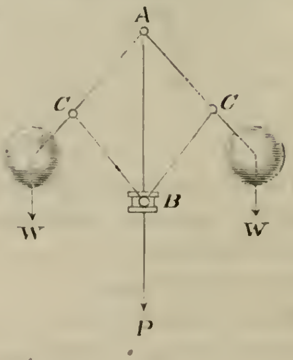


Fig. 3.

Fig. 4.



Wherever the joints of the arms may be situated, h is always the vertical distance from centre of ball to intersection of arm with the centre line of spindle, as shown in Figs. 2 and 3, which will be evident when it is considered that the centrifugal force is directly proportional to the radius of revolution.

In the above demonstration no account has been taken of the weight of arms and other gear connected with the governor.

Taking now (Fig. 4), $a\ A\ D$, — $b = A\ C$.

$W =$ weight of ball + half the weight of suspension rod.

P = weight of collar B + weight of other gear not balanced.

Then $$n_1 = \sqrt{\frac{2933}{h}\left(1 + \frac{P\ b}{W\ a}\right)} \qquad (4)$$

While the force exerted by P is added to the force W (Fig. 1) in proportion to its leverage, it cannot increase the centrifugal force, which, to attain equilibrium, has to be augmented by a greater number of revolutions, as obtained by Formula (4).

Fig. 5.

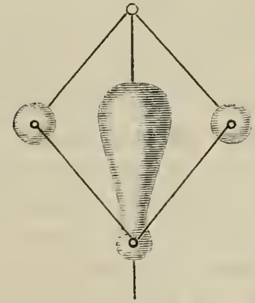
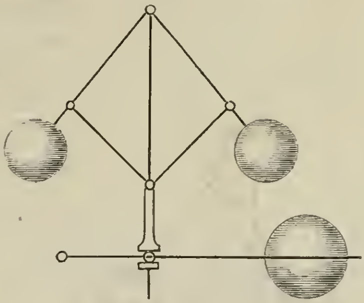


Fig. 6.



In Porter's governor, as first applied to the high-speed Allen engine, we find the extreme application of this idea (Fig. 5); the balls are made very small, and the heavy central weight is balanced by a greater number of revolutions.

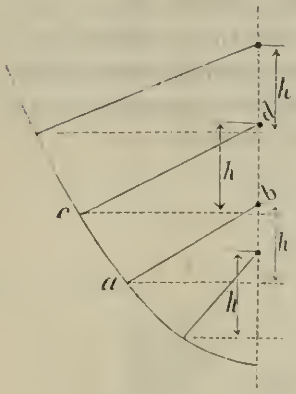
In place of a central weight, springs of different shapes have been applied, but, owing to the resistance of a spring increasing with its deflection, its action is somewhat different from that of a weight.

Fig. 6 shows the extra weight adjustable on a lever; by shifting it in or out the governor may be made to regulate for a smaller or greater number of revolutions.

The ordinary governor has the great disadvantage of not being isochronous or "equal timed"; at the normal speed of the engine, the arms can only be in one certain position, corresponding to a certain position of throttle or cut off. An increase or decrease of load will necessitate a change of throttle or cut off, and a corresponding position of governor, which can only be attained by a proportional decrease or increase in the number of revolutions.

To overcome this difficulty, a great many isochronous governors have been brought out, of which the "parabolic" governor may be taken as *theoretically* perfect.

Fig. 7.



In a common parabola (Fig. 7), all "subnormal" lines, *i. e.*, the vertical distance h of the intersection of a line normal to the curve (as $a\ b$, $c\ d$, etc.) with the centre line from its intersection with the parabola, are equal, and if the centre of a governor ball moves in a parabola, such a governor would be in equilibrium at all positions for the same number of revolutions, but would immediately go up or down at a change of speed. If now the changed position of the governor does not immediately produce a return to the normal speed (which is not always possible) the governor will fly to its extreme position, the throttle or cut off will be changed too far, and an opposite change of speed will send the governor to its other extreme, and thus the speed of the engine will continually change above and below its normal speed.

Fig. 8.

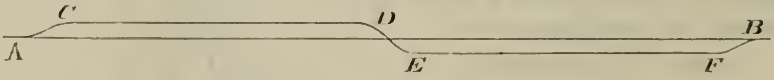


Fig. 9.

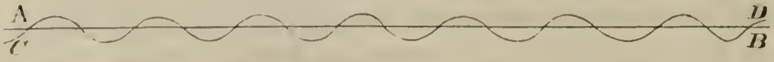
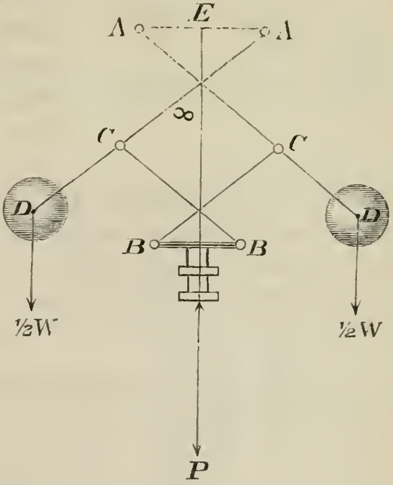


Fig. 8 illustrates graphically the action of the common governor: Line $A\ B$ represents the normal speed, $C\ D$ the increased speed, which, at a decrease of load, is necessary to keep the governor in a higher position, and this speed continues until an increase of load, requiring a lower position of governor (to effect corresponding change in throttle or cut off) makes a speed below the normal imperative, as shown at $F E$, and this speed again continues until another change of load requires a different speed and position of governor, or until a return to the normal load again establishes the normal speed and position.

The action of an isochronous governor, as described above, may be graphically illustrated by Fig. 9; where $A B$ is the normal speed and $C D$ the continual change of speed above and below $A B$, produced by the instability of the governor. To remedy this defect, some kind of resistance, which could not be overcome too quickly, would have to be opposed to the action of the governor, but at the cost of sensitiveness; an air cushion (which should be double acting) would be least objectionable, as a spring, owing to its resistance increasing with its compression (and *vice versa*), would destroy the isochronous property of the governor.

By a very slight modification the Watt governor may be made sufficiently isochronous for most practical purposes.

Fig. 10.



If the arms are suspended on the opposite side of the centre line (Fig. 10), an approximation to the parabolic governor is obtained, A being the centre of a circular arc, which, for a movement through a few degrees, will nearly coincide with a parabolic curve, and therefore such a governor will be nearly isochronous.

To show the percentage of deviation, the following example is a comparison of the ordinary Watt (Fig. 4) with the last-named governor:

Taking the arms $A D = a = 20''$ long, $B C = A C = b = 10''$, the normal angle $\propto = 30°$, the extreme angles $\propto_1 = 20°$ and $\propto_2 = 37°$, the lift of the sleeve will be, for all three systems of suspension, $= 2 b (\cos. \propto_1 - \cos. \propto_2)$ consequently each will do the same work.

h will be for Watt's governor $= a \cos. \propto$.

for 30° = 17·32 inches.
" 20° = 18·79 "
" 37° = 15·97 "

for improved governor: (taking $E A = B F = e = 2''$)

$$h = a \cos. \alpha - e \operatorname{cotg.} \alpha,$$

for 30° = 13,856 inches.
" 20° = 13·3 "
" 37° = 13,316 "

According to Formula (4), n_1 would then be, $\left(\text{if } \frac{P}{W} = \frac{2}{3}\right)$ for the ordinary governor—

for 30° = 52 rev. per min.
" 20° = 49·9 "
" 37° = 54·2 "

thus showing a deviation below the normal speed of $\frac{2{\cdot}1 \times 100}{52} =$ 4 per cent., and above of $\frac{2{\cdot}2 \times 100}{52} = 4{\cdot}2$ per cent., a total of 8·2 per cent.

For the improved governor n_1 would be

for 30° = 58·2 rev. per min.
" 20° = 59·4 "
" 37° = 59·4 "

a deviation of $\frac{1{\cdot}2 \times 100}{58{\cdot}2} = 2$ per cent.

A governor with arms jointed outside of centre line (Fig. 2) would have $h = a \cos. \alpha + e \operatorname{cotg.} \alpha$:

for 30° = 20·784 inches.
" 20° = 24·28 "
" 37° = 18·624 "

and n_1 would be:

for 30° = 47·5 rev. per min.
" 20° = 44 "
" 37° = 50·2 "

a deviation of $\frac{3{\cdot}5 \times 100}{47{\cdot}5} = 7{\cdot}35$ per cent below, and $\frac{2{\cdot}7 \times 100}{47{\cdot}5} = 6$ per cent. above the normal speed, a total of 13·35 per cent.

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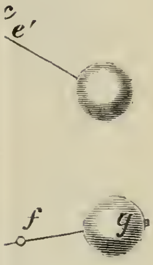

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WATER-TUBE AND FIRE-TUBE BOILERS.

By Chief Engineer ISHERWOOD, U. S. Navy.

TABLE CONTAINING THE DATA AND RESULTS OF THE EXPERIMENTS MADE, IN MARCH AND APRIL, 1873, AT THE WASHINGTON NAVY-YARD, BY CHIEF ENGINEERS LORING AND BAKER, UNITED STATES NAVY, ON TWO CYLINDRICAL TUBULAR BOILERS, OF THE SAME DIMENSIONS, BUT DIFFERING IN THE KIND AND ARRANGEMENT OF TUBES, ONE HAVING THE ORDINARY HORIZONTAL FIRE-TUBE RETURNED ABOVE THE FURNACES, AND THE OTHER HAVING VERTICAL WATER-TUBES RETURNED ABOVE THE FURNACES. THE OBJECT OF THE EXPERIMENTS WAS TO ASCERTAIN THE ECONOMIC VAPORIZATION UNDER ATMOSPHERIC PRESSURE BY EACH BOILER WHEN BURNING PENNSYLVANIA ANTHRACITE, A SEMI-BITUMINOUS COAL FROM THE CUMBERLAND MINES OF MARYLAND, AND A BITUMINOUS COAL OF UNKNOWN LOCALITY, UNDER THE EXPERIMENTAL CONDITIONS.

		HORIZONTAL FIRE-TUBE BOILER.		VERTICAL WATER-TUBE BOILER.			
		Anthracite.	Semi-bituminous coal.	Semi-bituminous coal.	Anthracite.		Bituminous coal.
	Designation of experiment,	A	B	C	D	E	F
BOILERS.	Square feet of grate surface,	36·00	36·00	36·00	36·00	36·00	36·00
	Square feet of heating surface, calculated for the inner surfaces of the tubes,	1019·00	1019·00	1104·00	1104·00	1104·00	1104·00
	Square feet of opening for draught over the bridge-walls,	5·55	5·55	5·55	5·55	5·55	5·55
	Square feet of opening for draught through the tubes,	7·24	7·24	5·55	5·55	5·55	5·55
TOTAL QUANTITIES.	Duration of the experiments, in consecutive hours,	30.	30·	30·	30·	30·	30·
	Total number of cubic feet of water vaporized from the temperature of the feed water,	2134.816	2061·670	2008·466	1532·830	1769·107	1888·815
	Total number of pounds of water vaporized from the temperature of the feed-water,	133187·0	128623·6	125304·3	98749·7	110367·4	117835·5
	Total number of pounds of coal consumed,	15336·0	15168·0	12979·0	10506·0	11280·0	13317·0
	Total number of pounds of refuse from the coal in ash, clinker and soot,	1608·0	2022·0	2284·0	1584·0	1320·0	1570·0
	Total number of pounds of combustible or gasifiable portion of the coal consumed,	13728·0	13146·0	10695·0	8922·0	9960·0	11747·0
	Per centum of the coal in refuse of ash, clinker and soot,	10·485	13·331	17·598	15·077	11·704	11·789
RATE OF COMBUSTION.	Pounds of coal consumed per hour,	511·200	505·600	432·633	350·200	376·000	443·900
	Pounds of combustible or gasifiable portion of the coal consumed per hour,	457·600	438·200	356·500	297·400	332·000	391·567
	Pounds of coal consumed per hour per square foot of grate surface,	14·200	14·044	12·018	9·728	10·444	12·331
	Pounds of combustible consumed per hour per square foot of grate surface,	12·711	12·172	9·903	8·261	9·222	10·877
	Pounds of coal consumed per hour per square foot of heating surface,	0·502	0·496	0·392	0·317	0·341	0·402
	Pounds of combustible consumed per hour per square foot of heating surface,	0·449	0·430	0·323	0·269	0·301	0·335
TEMPERATURES.	Temperature, in degrees Fahrenheit, of the external atmosphere,	35.	43.	43·	30·	47·	56·
	Temperature, in degrees Fahrenheit, of the gases of combustion in the uptake,	702·	—·	—·	338·	338·	358·
	Temperature, in degrees Fahrenheit, of the feed-water in the tank,	39·	39·	39·	39·	43·	43·
PRESSURE.	Steam pressure in boiler, in pounds per square inch above zero,	17·00	16·75	16·50	16·00	16·18	16·25
VAPORIZATION.	Total number of pounds of water that would have been vaporized had the feed-water been supplied at the temperature of 100 degrees Fahrenheit, and vaporized under the pressure of 29·92 inches of mercury,	141008·672	136151·660	132607·757	104461·845	116359·742	123869·721
	Total number of pounds of water that would have been vaporized had the feed-water been supplied at the temperature of 212 degrees Fahrenheit and vaporized under the pressure of 29·92 inches of mercury,	157484·215	152059·706	148101·731	116667·233	129955·288	138342·737
	Pounds of water vaporized from 100 degrees Fahrenheit by one pound of coal,	9·1946	8·9762	10·2171	9·9431	10·3156	9·3016
	Pounds of water vaporized from 100 degrees Fahrenheit by one pound of combustible,	10·2716	10·3569	12·3990	11·7083	11·6827	1054·48
	Pounds of water vaporized from 212 degrees Fahrenheit by one pound of coal,	10·2689	10·0250	11·4109	11·1048	11·5204	10·3884
	Pounds of water vaporized from 212 degrees Fahrenheit by one pound of combustible,	11·4717	11·5670	13·8477	13·0764	13·0477	11·7769

The last-mentioned construction is thus shown to be most deficient in isochronism, and many attempts have been made to correct this fault. One of the latest is the Gardner governor (Figs. 11 and 12), where a toe on the end of the suspension arm presses transversely against a toggle joint combination, which is connected to a weight or spring pressing upwards, thus tending to compress the toggle joint vertically, forcing it outward against the toes of the governor arms.

Fig. 11.

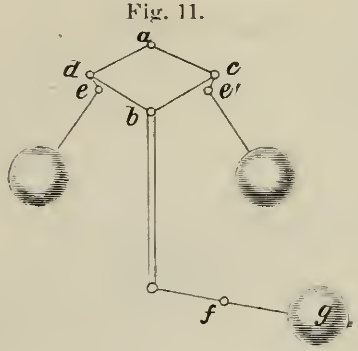
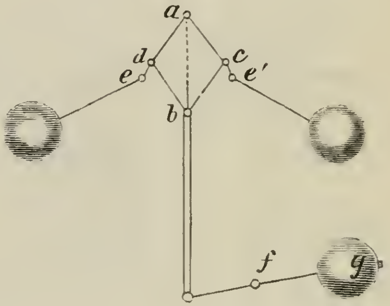


Fig. 12.



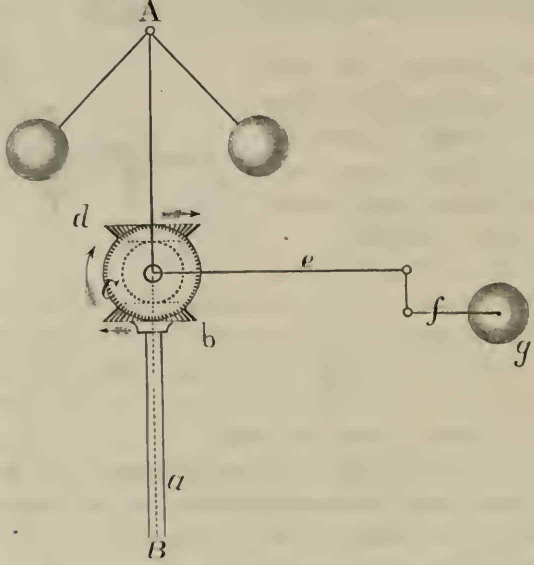
When the governor arms are down, the toggle joint being more compressed vertically, exerts greater pressure horizontally against the governor arms; to counteract this the centrifugal force must be increased by a few revolutions, bringing the speed nearer to the normal, and exactly the opposite action occurs, when the governor arms move above their normal position.

A recent test of this governor at the Franklin Institute gave a deviation of from 6 to 14 per cent. from the mean speed, hence its isochronism is very far from being perfect.

Siemens' differential or chronometric governor consists of a conical pendulum with heavy balls, driven by a train of bevel wheels, as shown in Fig. 13. The shaft *a* receives its motion from the engine, and has keyed on its end a bevel wheel, *b*, which gears into another similar wheel, *e*, that can vibrate around the vertical axis *A B*, but is held in position by the weight *g*, acting through lever *f* and rod *e*. The wheel *c* gears into the wheel *d*, which is fixed on the shaft of the pendulum, and thereby the latter is put into motion.

The weight *g* is adjusted to balance exactly the tangential force of weight *a*, necessary to drive the pendulum at the normal speed; if now the engine (and with it shaft a) changes its speed, the pendulum, on account of its inertia, will still continue its uniform speed, which causes the wheel c to swing around the axis A B, and the lever f being fixed on a shaft connected with the throttle or cut off, these will be changed correspondingly.

Fig. 13.

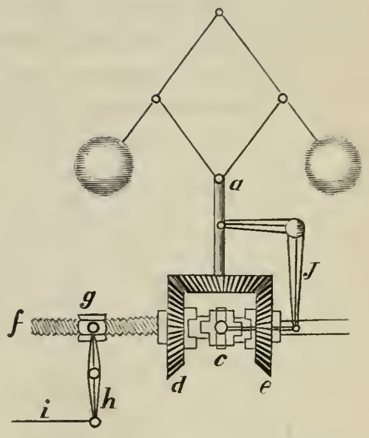


As the power necessary to drive the pendulum at a certain speed may be considered uniform, the wheel c will only be at rest as long as this speed is maintained, but (within a certain limited travel of lever f) it may be in different positions; and as thereby different positions of throttle or cut off, corresponding to the load to be overcome by the engine, can be attained without a permanent change of speed, the governor may be called perfectly isochronous.

As in some cases the shifting of throttle or cut off gear may require more force than a change in speed of the pendulum, the latter has an ingenious arrangement, by which a slight rise or fall of the pendulum balls will increase that force.

The ordinary Watt governor may act indirectly upon the throttle or cut off, as shown in Fig. 14. The sleeve a of the governor is connected by lever j to a clutch, c, which, being between two bevel

Fig 14.



wheels, *d* and *e*, running in opposite directions, is put into gear with either by a rise or fall of the governor balls. This clutch slides upon a feather in the screw *f*, which, by means of nut *g*, lever *h* and rod *i*, can move the throttle or cut off.

Here the governor acts with perfect isochronism, as it is evident that at any change of speed the clutch will remain in gear until the normal position and number of revolutions is regained.

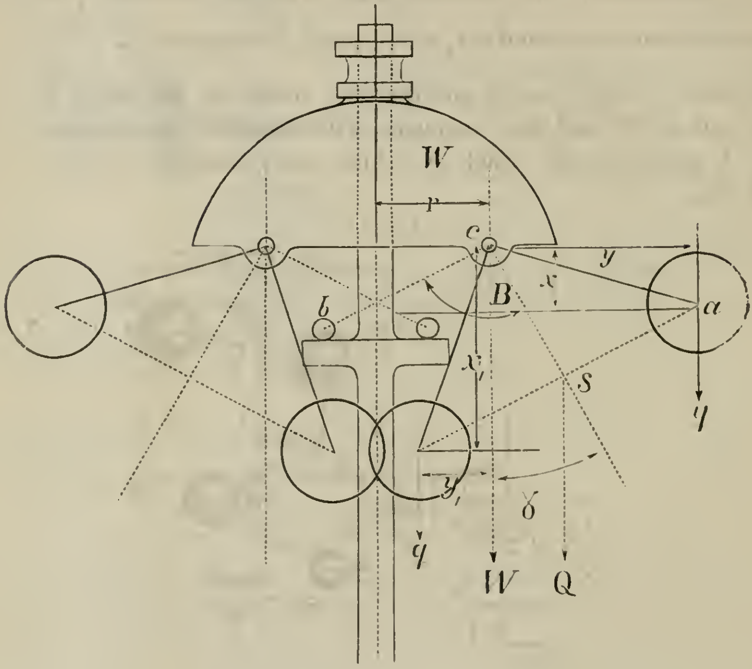
As the force moving the throttle is derived from the engine direct, the governor is extremely sensitive, but this advantage is sometimes more than counterbalanced by the time required to effect any considerable change in the throttle or cut off, and for this reason, and on account of the additional complication, this system is but little used.

Buss's "Cosine Governor" derives its name from the fact that its moment of centrifugal force is proportional to the cosine of the angle of deviation γ for an entire revolution round its point of suspension *c*. When connected to a central weight, *W*, in such a way that the moment of this weight, acting against an arm, *b c*, of the pendulum, is also proportional to the cosine of the angle of deviation, a perfect isochronous governor is obtained, having the greatest possible range of motion, consequently possessing great power and sensitiveness. Fig. 15 shows that each arm of the pendulum has two balls, fixed at 90° to each other, which are suspended from a point, *c*, situated in the central weight; the arms *c b* bear against a fixed shoulder on the spindle, and the centrifugal force of the balls has to balance both the central weight *W* and the weight of the balls, hence all parts are utilized to increase the power and sensitiveness. By a small change of the angle *s c b*, a nearly uniform degree of stability with only a limited deviation from isochronism can be obtained, thus obviating the most serious defect of isochronous governors—their instability.

The theory of this governor, as given by the inventor, is as follows:

If Q = total weight of a system of bodies suspended at c,
n = number of revs. per second; then
ω = angular velocity $= 2\pi n$.
r = distance of point of suspension from axis of revolution.
q = weight of some part of Q,
x and y co-ordinates of q with regard to c,

Fig. 15.



The centrifugal force of q will be

$$c = \frac{\omega^2}{g}\, q\,(r + y)$$

and its moment $m_c = x\,\frac{\omega^2}{g}\,q(r + y)$ and the centrifugal moment of the entire system $M_c = x_1 \Sigma q\,\frac{\omega^2}{g}\,(r + y_1) = \Sigma q\,\frac{\omega^2}{g}\,x_1 r + \Sigma q\,\frac{\omega^2}{g}\,x_1 y_1 \qquad (5)$

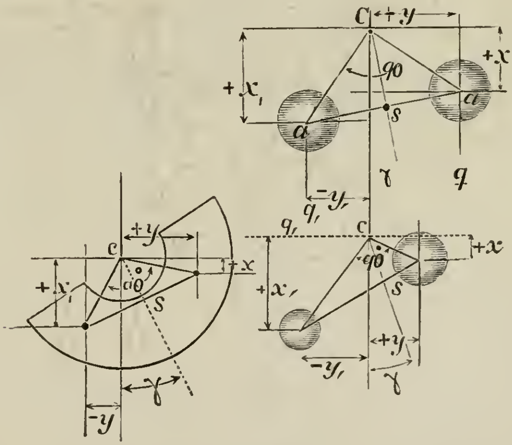
If x_1 and y_1 are the co-ordinates of the centre of gravity of the entire system, $x_1 = \frac{\Sigma q x}{Q}$ and $y_1 = \frac{\Sigma q y}{Q}$ *i. e.* the distance of the common centre of gravity of a system of bodies from any point is equal to the sum of the moments of the parts with regard to this same point, divided by the sum of their weights.

If l is the distance $c\ s$, $x_1 = l \cos. \gamma$ and

$$M_c = \frac{\omega^2}{g} r\ Q\ l \cos. \gamma + \frac{\omega^2}{g} \Sigma\ q\ x_1\ y_1 \qquad (7)$$

If the weight of the revolving body is divided into such parts that their moments, $q\ x\ y$ and $q\ x_1\ y_1$ are equal, but opposite, $\Sigma\ q \frac{\omega^2}{g}\ x_1\ y_1$ (Formula 7) will be $= O$, and this will always be the case where the parts are at 90° and their moments, with regard to their common centre of gravity, s, are equal, of which some examples are given in Fig. 16.

Fig. 16.



In each of these cases (taking $f = c\ a$) : $q\ x\ y + q_1\ x_1\ (-y_1) = q\ f^2 \cos. (45+\gamma) \sin. (45+\gamma) + q\ f^2 \cos. (45-\gamma)\ (-\sin. 45-\gamma) = O$,

hence $M_c = \frac{\omega^2}{g} r\ q\ l \cos. \gamma$. (8)

i. e., proportional to the cosine of the angle γ.

In applying the central load, W, the weight of the balls, having the moment $= Q\ l \sin. \propto$, must be taken into account, and the angle $c\ s\ b = \beta$ will have to be so arranged that

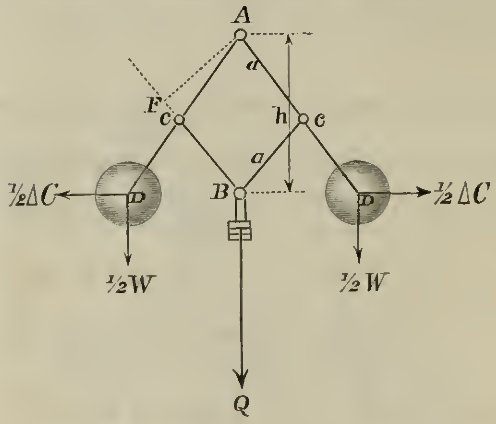
$$Q \frac{\omega^2}{g} r\ l \cos. \gamma = (W + Q)\ b \sin. (\beta - \gamma) + Q\ l \sin. \gamma,$$

to make the governor perfectly isochronous, and this is obtained by making

$$\cos.\,\beta = \frac{Q\,l}{(W + Q)\,b}$$

From Formula (2) it is apparent that theoretically the weight of the balls has no influence on the position or number of revolutions of a pendulum, as the centrifugal force increases in the same ratio with an increase of weight, but in its practical application this point is of some importance; to overcome the resistance of the gear there must be a certain increase or decrease of the centrifugal force before the governor can act.

Fig. 17.



If n = normal number of revolutions,
n_1 = lowest and
n_2 = highest number of revolutions permitted,

then $\delta = \frac{n_2 - n_1}{n}$ = total deviation.

For n the centrifugal force is:

$$C = (2\,\pi\,n)^2\,\frac{W}{g}\,r$$

and for n_2:

$$C_2 = (2\,\pi\,n_2)^2\,\frac{W}{g}\,r$$

and the difference:

$$\Delta C' = 4\,\pi^2\,(n_2^2 - n^2)\,\frac{W}{g}\,r$$

or, approximately:

$$\Delta C' = \delta\,4\,\pi^2\,n^2\,\frac{W}{g}\,r;$$

its leverage being $= h = \dfrac{g}{4\,\pi^2\,n^2}$,

its moment is:

$$\Delta C' h = \delta\,\frac{4\,\pi^2\,n^2\,W\,r\,g}{4\,\pi^2\,n^2\,g} = \delta\,W\,\mathrm{r}. \tag{9}$$

If $Q =$ resistance of gear referred to sleeve B,
$b = A\,C$,
$a = A\,D$,

this action of Q will produce a force $= \dfrac{Q}{\cos.\,\alpha}$ in the direction of BC, which, with regard to A, will act with a leverage $A\,F = b\,\sin.\,2\,\alpha$, hence its moment $= \dfrac{Q\,b\,\sin.\,2\,\alpha}{\cos.\,\alpha}$. (10)

Putting $Q\,\dfrac{b\,\sin.\,2\,\alpha}{\cos.\,\alpha} = \delta\,W\,r$, the weight of balls is found:

$$W = \frac{Q\,b\,\sin.\,2\,\alpha}{\delta\,r\,\cos.\,\alpha}.$$

and as $r = a\,\sin.\,\alpha$, and $\dfrac{\sin.\,2\,\alpha}{\cos.\,\alpha\,\sin.\,\alpha} = 2$, $W = \dfrac{Q\,2\,b}{\delta\,a}$

or each ball:

$$\frac{W}{2} = \frac{Q\,b}{\delta\,a} \tag{11}$$

showing that, for any considerable resistance, very heavy balls or an extensive deviation of speed from the normal, would be needed, to effect a change in the throttle or cut off gear.

A governor, loaded with a central weight (Fig. F.), has an advantage in this respect, as its greater angular velocity (necessary to balance the central weight) will give a greater differential moment of centrifugal force for a certain change of speed than the ordinary construction.

Here $h = \dfrac{g}{4\,\pi^2\,n^2}\left(1 + \dfrac{P\,b}{W\,a}\right)$ [see Formula (4)], making the differential moment of centrifugal force: $\Delta\,C h = \delta\,\dfrac{4\,\pi^2\,n^2\,W\,r\,g}{4\,\pi^2\,n^2\,g}\left(1 + \dfrac{P\,b}{W\,a}\right)$

$$= \partial \; W \, a \sin. \; x \left(1 + \frac{P \, b}{W \, a}\right) \qquad (12)$$

and putting this equal to the moment of resistance of gear:

$$= \frac{Q \, b \sin. 2 \; x}{\cos. \; x} \text{ will give}$$

$$W = \frac{Q \, 2 \, b}{\partial \; a \left(1 + \dfrac{P \, b}{W \, a}\right)}; \qquad (13)$$

Thus if $\frac{P \, b}{W \, a} = 1$, the weight of balls will only be one-half of that needed for the ordinary governor, to overcome the same resistance, or balls of the same weight would already act at one-half the deviation of speed from the normal, thus doubling the sensitiveness of the governor.

In conclusion it might be well to point out that a sensitive governor is not the only thing necessary to ensure uniformity of motion.

Not only the load may be variable, but the pressure at different parts of a revolution also varies, especially in engines working expansively, and when the steam is cut off, the influence of the governor is cut off also, hence the fly-wheel ought to be heavy enough to store up any excess of work developed during that time, without greatly increasing the speed, otherwise the governor, especially if it is very sensitive, will always be flying up and down, thus defeating its very object.

Systematic Errors.—Otto Struve states that his measurements, especially those of direction, are subject to very large systematic errors, depending upon the angle between the direction of the two stars and the vertical circle at the moment of observation. By means of measurements taken upon artificial stars, he has determined the corrections with great exactness and has proved that the same laws of error have existed in his case for the last 35 years. He supposes that they have a physiological origin depending upon the construction of the observer's eyes. He thinks it desirable that every astronomer who is employed upon similar measurements should make special experiments so that the results of different observers can be more satisfactorily compared.—*Comptes Rendus.* C.

WATER-TUBE AND FIRE-TUBE BOILERS.

An Account of the Experiments made by Chief Engineers Loring and Baker, U. S. Navy, on a Horizontal Fire-Tube and a Vertical Water-Tube Boiler, at the Washington Navy Yard, to ascertain their relative Economic Vaporizations with different kinds of Coal.

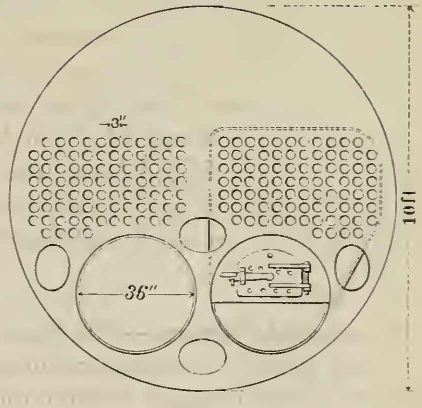
By Chief Engineer Isherwood, U. S. Navy.

(Continued from vol. lvii, page 24.)

The Horizontal Fire-Tube Boiler.

The shell of the horizontal fire-tube boiler is a cylinder with flat ends at right angles to its axis. The front end is also the front tube-plate. This cylinder is ten feet in diameter and nine feet in length, externally. The uptake, which is of sheet iron bolted to the front end of the cylinder, projects beyond this length. The plates of the shell are $\frac{11}{16}$ths of an inch thick, and double riveted. The flat ends of the shell above the tube-boxes are stayed directly across with iron rods $1\frac{5}{8}$ inches in diameter and 10 inches between axes, attached to double angle iron riveted vertically to the ends. All other flat surfaces are stayed with socket-bolts $1\frac{1}{8}$ inch in diameter and 6 inches between centres.

Fig. 3.

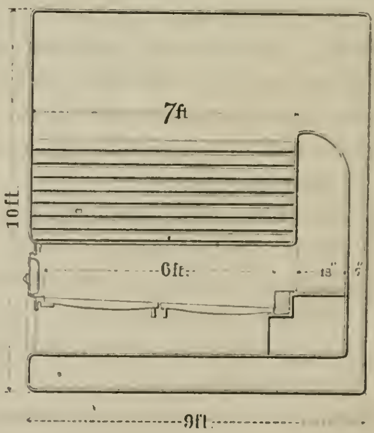


There are two furnaces contained in horizontal cylinders of 3 feet internal diameter and 7 feet extreme length. The axes of these cylinders are in the same horizontal plane and 42 inches apart. The cylinders are composed of iron plates $\frac{1}{2}$ inch thick, butted, and double-riveted to inner welts below the grate bars; they are single riveted to the boiler-shell and are in three lengths, flanged where the lengths meet, and single-riveted thereby through a ring placed between them. The grates within these cylinders are 6 feet in extreme length, composed of cast iron bars in two lengths of 3 feet each. The bridge-wall is of cast iron faced with fire-brick and is 6 inches high above the level of the grates. The top of the grates is 18 inches below the crown of the furnace, at the front, and 21 inches below it at the back.

Each furnace has a separate back connection 18 inches long, lengthwise the boiler, with its top rounded on a quadrantal arc of 14 inches radius. Its back is flat and separated from the back end of the boiler-shell by a flat water-space six inches wide, including thicknesses of metal. The bottom of the connection is a horizontal extension of the bottom of the cylinder containing the furnace and the sides are flat. The inner side is vertical and rises from the horizontal diameter of the furnace. The outer side, at top, is vertical for the depth occupied by the tubes, and thence slopes inwards on a tangent to the cylinder containing the furnace. The cast iron bridge-wall of the furnace is extended clear across the connection so as to occupy the whole of the lower portion.

From each back connection to the uptake proceed 86 horizontal fire-tubes of seamless brass, $\frac{1}{9}$th of an inch thick; 70 of them are expanded on one side and riveted over the other side of their tube-plates, and the remaining 16 act as stays, having nuts upon their outer ends. The boiler thus contains 172 tubes, of three inches outside diameter, and 6 feet $10\frac{5}{8}$ inches length between the tube plates, which are of $\frac{11}{16}$ths inch thick iron. These tubes are arranged in twenty-four rows horizontally and eight rows vertically, but the number in all the rows is not equal. The top row contains twenty-two tubes, the bottom row contains eight tubes, the row next to the bottom, twenty-two tubes, and each of the other rows twenty-four. The two groups of tubes are separated by a water space 11 inches wide in the clear. The distance between the axes of the tubes of each group is, vertically, 4 inches, and, horizontally, $4\frac{1}{10}$ inches.

Fig. 4.



All the tubes discharge into one uptake, which at the top delivers the gases of combustion into a horizontal sheet iron flue connecting the uptake of the horizontal fire-tube boiler with that of the vertical water-tube boiler, and from the centre of this flue, the chimney, common to both boilers, rises. The uptake has the usual doors for access to the tubes for sweeping, etc., and the furnace doors were thoroughly perforated for the admission of air above the incandescent fuel on the grates.

The following are the principal dimensions and proportions of the horizontal fire-tube boiler :

Diameter of the shell,	10 ft.
Length of the shell, exclusive of the uptake,	9 ft.
Number of furnaces,	2
Breadth of furnaces,	3 ft.
Length of grates,	6 ft.
Total area of grate surface,	36 sq. ft.
Total number of tubes,	172
External diameter of tubes,	3 in.
Internal diameter of tubes,	$2\frac{7}{8}$ in.
Length of tubes in clear of tube-plates,	$82\frac{5}{8}$ in.
Total cross area for draught above the bridge-walls,	5·55 sq. ft.
Total cross area for draught through the tubes,	7·24 sq. ft.
Cross area of the chimney,	12·57 sq. ft.
Diameter of the chimney,	4 ft.
Height of the chimney above the level of grate-bars,	60 ft.
Heating surface in the two furnaces,	64 sq. ft.
Heating surface in the 172 tubes, measured on their inner circumference,	861·24 sq. ft.
Heating surface in the two back connexions,	76·5 sq. ft.
Heating surface in the one uptake,	17·26 sq. ft.
Total water heating surface in the boiler,	1019 sq. ft.
Square feet of water heating surface per square foot of grate surface,	28·30
Square feet of grate surface per square foot of cross area above bridge-walls,	6·49
Square feet of grate surface per square foot of cross area through the tubes,	4·97
Square feet of grate surface per square foot of cross area of chimney,	2·87
Water room to 6 inches above tubes,	325 cubic ft.
Steam room from 6 inches above tubes,	161 cubic ft.
Greatest height of steam room,	2·35 ft.

MANNER OF MAKING THE EXPERIMENTS.

With the precedingly described boilers six experiments were made, of thirty consecutive hours duration each, and in precisely the same manner. Of these experiments, two were made with the horizontal fire-tube boiler, one being made with Pennsylvania anthracite, and the other with semi-bituminous coal from the Cumberland mines of Maryland. The remaining four experiments were made with the vertical water-tube boiler and, of these, two were made with Pennsylvania anthracite and were nearly repetitional; one was made with semi-bituminous coal from the Cumberland mines, and the last was made with a bituminous caking coal of unknown locality.

The anthracite was of better quality than the average, and the semi-bitumninous coal was of poorer quality than the average, in this respect—that the former had a less, and the latter had a greater percentage of refuse than the average. The average proportion of refuse in fair merchantable anthracite is one-sixth, and in fair merchantable semi-bituminous coal, one-eighth. Of course, the quality of the gasifiable portion of these coals is not affected by their percentage of refuse.

The vaporization took place under the atmospheric pressure, increased slightly by the resistance opposed by the escape pipe to the effluent steam.

Although the boilers stood side by side in the boiler house, and delivered their gases of combustion into the same chimney, they were not experimented with simultaneously. The experiments with the horizontal fire-tube boilers were made first, and those with the vertical water-tube boiler last, a partition of brick masonry being temporarily placed in the horizontal flue connecting the uptakes of the boilers, just beyond the chimney, in each case. Of course, by this arrangement the entire chimney, which was of sufficient cross area for both boilers, was used with each. This, and the fact that the experiments were made at different times under different atmospheric conditions, prevented the possibility of ascertaining the maximum rates of combustion for the two boilers. In the experiments as actually made, there were no attempts to force the fires, which were allowed to burn without further attention than what was required to keep them level, clean, free of holes and about ten inches thick.

The experiments were made during the months of March and April, 1873, and the boilers were thoroughly protected by a non-conducting covering of asbestos.

In commencing an experiment, the fires, of 10 inches thickness, were brought to steady action with the steam freely blowing off through the escape pipe, and with the water in the boiler at about 6 inches above the top of the tubes. The fires were then carefully leveled, the height of water in the boiler exactly adjusted, the thickness of the fires noted and the experiment held to commence. Up to this time no account was taken of the coal and water; but, from this time to the expiration of the thirty hours, all the coal thrown into the furnaces was accurately weighed, and all the feed-water admitted to the boiler was accurately measured in a tank, and the quantities noted hourly. At the end of the experiment the fires were thoroughly cleaned and made of the same thickness as at the commencement, with the water level at precisely the same mark.

All the coal and all the refuse from it were weighed on the same scales in the same iron tub, counterbalanced to prevent error. The same firemen were employed throughout.

During the experiments, regular watches were kept by Assistant Engineers of the Navy, who entered in the columns of a tabular log all the necessary observations from hour to hour.

The data and results of the experiments will be found in the following table, in which the headings of the columns and the descriptions of the quantities on the lines are so full that no further explanation is needed. The observed data are from the original notes of Chief Engineer Baker, but the computations were made by the writer.

RESULTS.

In order that the results of the experiments should be strictly comparable, as regards the economic vaporization of water, they should have been made with equal quantities of water vaporized in equal time, which implies equal quantities of the heat produced by the fuel, absorbed by the water in equal time. This condition, however, does not obtain in the experiments as perfectly as could be desired, but the departures from it were not sufficiently wide to materially affect the comparisons, owing to the facts that the rate of combustion at the maximum was moderate, and that the heat-absorbing surface was great in proportion to the quantity of heat thrown upon it per hour.

In the case of the two experiments D and E, made on anthracite with the vertical water-tube boiler, 116,667·233 and 129,955·288 pounds of water were vaporized during the experiments from the temperature of 212 degrees Fahrenheit, on the supposition that the water was supplied at that temperature, and the economic results were respectively 13·0764 and 13·0477 pounds of water vaporized from the temperature of 212 degrees Fahrenheit by one pound of the combustible portion of the anthracite. The difference in the potential vaporization appears here not to have influenced the economic vaporization. It is undoubted, however, that to some extent—more or less, according to circumstances,—increased potential vaporization is accompanied by decreased economic vaporization; but, when the maximum potential vaporization is not great, and the heat-absorbing surface is great in proportion to the quantity of heat absorbed in a given time, the effect of any difference in the potential vaporization on the economic vaporization becomes sufficiently small to be neglected from a practical point of view.

For the comparison of the economic vaporizations by the horizontal fire-tube and the vertical water-tube boilers, *when burning anthracite*, we have experiments A and E, experiment D not being included because of its less potential vaporization. In experiment A, made with the horizontal fire-tube boiler, the economic vaporization from the temperature of 212 degrees Fahrenheit was 11·4717 pounds of water per pound of the combustible portion of the anthracite; while, in experiment E, made with the vertical water-tube boiler, it was 13·0477 pounds of water. Hence, *with anthracite*, the vertical water-tube boiler, under the experimental conditions, vaporized per pound of fuel $\left(\frac{13{\cdot}0477-11{\cdot}4717\times 100}{11{\cdot}4717}\right)=13{\cdot}74$ per centum more water than the horizontal fire-tube boiler. This percentage would have been less had the potential vaporizations in the two experiments been equal.

For the comparison of the economic vaporizations by the horizontal fire-tube and the vertical water-tube boilers, *when burning semi-bituminous coal*, we have experiments B and C, in which the potential vaporizations were nearly equal. In experiment B, made with the horizontal fire-tube boiler, the economic vaporization from the temperature of 212 degrees Fahrenheit was 11·5670 pounds of water per pound of the combustible portion of the semi-bituminous coal, while, in experiment C, made with the vertical water-tube boiler, it was 13·8477 pounds of water. Hence, *with semi-bituminous coal*, the vertical water-tube boiler, under the experimental conditions, vaporized per pound of fuel $\left(\frac{13{\cdot}8477-11{\cdot}5670\times100}{11{\cdot}5670}\right)=19{\cdot}72$ per centum more water than the horizontal fire-tube boiler.

It will be remembered that with equal weights of the combustible portion of *anthracite*, the vertical water-tube boiler was economically somewhat less than 13·74 per centum superior to the horizontal fire-tube boiler, and we now see this superiority increased to 19·72 per centum for equal weights of the combustible portion of *semi-bituminous coal*. To what should this increase be attributed? The distillation of semi-bituminous coal in the furnace, previous to the incandesence of its fixed carbon, produces a very much larger quantity of combustible gases than the similar distillation of anthracite. The fixed carbon of both coals is consumed on the grate in the solid form, but the combustion of the gases takes place after their distillation, in the furnace above the fixed carbon, and in the tubes also, if heat and oxygen enough be present, *and the gases be sufficiently intermingled with the latter*. In the horizontal fire-tube there is nothing to produce this necessary intermingling; there is no obstruction, the gases pass rapidly through it in parallel streaks unmixed; but, with the vertical water-tubes, the tubes themselves are mechanical mixers, standing, as they do, in and across the current of the gases. To their position, therefore, may be attributed the marked difference in the amount of their economic gain when vaporizing water with semi-bituminous coal and when vaporizing it with anthracite—the one a very gas-producing and the other almost a non-gas-producing fuel. The superiority of the vertical water-tubes may be due not only to their better absorption of heat, but to their contributing to its development by their mechanical mixing of the coal-gases and the atmospheric oxygen. If these hypotheses are correct, the vertical water-tube boiler, comparatively with the horizontal fire-tube boiler, should have a greater economic superiority in the vaporization of water the more gas-producing the coal consumed.

It will be observed that the foregoing comparisons between the two boilers are for substantially equal potential vaporizations per hour or, roughly, for equal rates of combustion; but had each boiler been fired to its maximum, about fifty per centum more coal would have been consumed in the same time in the horizontal fire-tube boiler than in the vertical water-tube boiler, and with about twenty-five per centum less economy per pound of fuel, producing about twenty-five per centum more steam per hour.

As regards the relative economic efficiency of the combustible portion of anthracite and of semi-bituminous coal, *consumed in the horizontal fire-tube boiler*, a comparison of the economic vaporizations per pound of these combustible portions, given in experiments A and B, shows that the two fuels were about equal, the results being, in experiment A, 11·4717 pounds of water vaporized from the temperature of 212 degrees Fahrenheit by one pound of the combustible portion of anthracite, and 11·5670 pounds of water vaporized from the same temperature by the pound of the combustible portion of semi-bituminous coal.

If, however, the comparison be made for the pound of coal in the two cases, assuming the refuse in the anthracite at one-sixth and in semi-bituminous coal at one-eighth of the gross weight, which are the averages in practice, then the economic vaporization of water from the temperature of 212 degrees Fahrenheit per pound of coal becomes $(11{\cdot}4717 \times \frac{5}{6} =) 9{\cdot}5598$ pounds for the anthracite and $(11{\cdot}5670 \times \frac{7}{8} =)$ 10·1213 pounds for the semi-bituminous coal, or the latter is $\left(\frac{10{\cdot}1213 - 9{\cdot}5598 \times 100}{9{\cdot}5598}\right) = 5{\cdot}72$ per centum superior to the former.

As regards the relative economic efficiency of the combustible portion of anthracite and of semi-bituminous coal, *consumed in the vertical water-tube boiler*, a comparison of the economic vaporizations per pound of these combustible portions, given in experiments E and C, shows that the pound of the combustible portion of the anthracite vaporized in experiment E 13·0477 pounds of water from the temperature of 212 degrees Fahrenheit, while the pound of the combustible portion of the semi-bituminous coal vaporized, in experiment C, 13·8477 pounds of water from the same temperature; hence, the economic efficiency of a pound of the combustible portion of semi-bituminous coal was $\left(\frac{13{\cdot}8477 - 13{\cdot}0477 \times 100}{13{\cdot}0477}\right) = 6{\cdot}13$ per centum greater than that of a pound of the combustible portion of anthracite.

If, however, the comparison be made for the pound of coal in the two cases, assuming, as before, the refuse in anthracite at one-sixth and in semi-bituminous coal at one-eighth of the gross weight, then the economic vaporization of water from the temperature of 212 degrees Fahrenheit per pound of coal becomes $(13{\cdot}0477\times\frac{5}{6}=)10{\cdot}8731$ pounds for the anthracite and $(13{\cdot}8477\times\frac{7}{8}=)12{\cdot}1167$ pounds for the semi-bituminous coal, or the latter is $\left(\frac{12{\cdot}1167-10{\cdot}8731\times100}{10{\cdot}8731}\right)=$ 11·44 per centum superior to the former.

To determine the economic efficiency of the combustible portion of the caking bituminous coal relatively with that of the combustible portion of anthracite and of semi-bituminous coal, the economic vaporization of water from the temperature of 212 degrees Fahrenheit, given in experiment F, by the pound of the combustible portion of the caking bituminous coal, will be compared with that given in experiment E by the pound of the combustible portion of anthracite and with that given in experiment C by the pound of the combustible portion of semi-bituminous coal, all three of the experiments having been made with the vertical water-tube boiler.

In experiment E, the pound of the combustible portion of the caking bituminous coal vaporized from the temperature of 212 degrees Fahrenheit 11·7769 pounds of water. In experiment E, the pound of the combustible portion of anthracite vaporized from the same temperature 13·0477 pounds of water. And, in experiment C, the pound of the combustible portion of semi-bituminous coal vaporized from the same temperature 13·8477 pounds of water. Hence, the economic vaporation by the pound of the combustible portion of caking bituminous coal was $\left(\frac{13{\cdot}0477-11{\cdot}7769\times100}{13{\cdot}0477}\right)=9{\cdot}74$ per centum less than by the pound of the combustible portion of the anthracite. And the economic vaporization by the pound of the combustible portion of caking bituminous coal was $\left(\frac{13{\cdot}8477-11{\cdot}7769\times100}{13{\cdot}8477}\right)=14{\cdot}95$ per centum less than by the pound of the combustible portion of semi-bituminous coal.

Radiometer Pressure.—In some recent experiments, Crookes has employed the torsion balance in order to estimate the molecular pressure within the radiometer. He finds that it varies between 7 ten-millionths and 9 four-millionths of an atmosphere.—*Comptes Rendus.*

CIRCUMSTANCES INFLUENCING THE EFFICIENCY OF DYNAMO-ELECTRIC MACHINES.

BY PROFS. EDWIN J. HOUSTON and ELIHU THOMSON.*

During the recent competitive trials made at the Franklin Institute as to the relative efficiency of some different forms of Dynamo-Electric Machines, the authors having been entrusted with the work of determining the relations between the mechanical power consumed and the electric and thermic effects produced, took the opportunity thus afforded to make a careful study of many interesting circumstances which influence the efficiency of these machines.

It is purposed in the present paper to select from the many circumstances thus noticed, a few of the more interesting, reserving the others for future consideration.

It will readily be understood that from the comparatively new field in which we have been working, no reliable data of the electrical work of these machines having before been obtained, difficulties constantly arose owing to necessary conditions of operation, and new developments as to the behavior of the machines under varied conditions, were constantly met.

A convenient arrangement of the particular circumstances we are about to discuss may be, 1st, Those affecting the internal work of the machine; 2d, Those affecting the external work, and 3d, The relations between the internal and external work.

The mechanical energy employed to give motion to a Dynamo-Electric Machine is expended in two ways, viz., 1st, In overcoming friction and the resistance of the air; and, 2d, In moving the armature of the machine through the magnetic field, the latter of course constituting solely the energy available for producing electrical current. The greatest amount of power expended in the first way was noticed to be about 17 per cent. of the total power employed. This expenditure was clearly traceable to the high speed required by the machine. The speed therefore required to properly operate a machine is an important factor in ascertaining its efficiency.

The above percentage of loss may not appear great, but when it is compared with the total work done in the arc, as heat, constituting as it did in this particular instance over 50 per cent. of the latter, and about 33 per cent. of the total work of the circuit, its influence is not to be disregarded. In another instance the work consumed as friction was equal to about 80 per cent. of that appearing in the arc as heat, while in the Gramme machine experimented with, this percentage fell to 20 per cent. of that which appeared in the arc as heat, and was only about 7 per cent. of the total power consumed in driving the machine.

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* *Read before the American Philosophical Society, Nov.* 1, 1878.

In regard to the second way in which mechanical energy is consumed, viz.: in overcoming the resistance necessary to move the armature through the magnetic field, or in other words, to produce electrical current, it must not be supposed that all this electrical work appears in the circuit of the machine, since a considerable portion is expended in producing what we term the local action of the machine, that is local circuits in the conducting masses of metal, other than the wire, composing the machine.

The following instances of the relation between the actual work of the circuit, and that expended in local action, will show that this latter is in no wise to be neglected. In one instance an amount of power somewhat more than double the total work of the circuit was thus expended. In this instance also it constituted more than five times the total amount of power utilized in the arc for the production of light. In another instance it constituted less than one-third the total work of the circuit, and somewhat more than one-half the work in the arc.

Of course work expended in local action is simply thrown away, since it adds only to the heating of the machine. And since the latter increases its electrical resistance, it is doubly injurious.

The local action of dynamo-electric machines is analogous to the local action of a battery, and is equally injurious in its effects upon the available current.

Again, in regard to the internal work of a machine, since all this is eventually reduced to heat in the machine, the temperature during running must continually rise until the loss by radiation and convection into the surrounding air, equal the production, and thus the machine will acquire a constant temperature. This temperature, however, will differ in different machines according to their construction, and to the power expended in producing the internal work, being, of course, higher when the power expended in producing the internal work is proportionally high.

If therefore a machine during running acquires a high temperature when a proper external resistance is employed, its efficiency will be low. But it should not be supposed that because a machine when run without external resistance, that is on short circuit, heats rapidly, that inefficiency is shown thereby. On the contrary, should a machine remain comparatively cool when a proper external resistance is employed, and heat greatly, when put on short circuit, these conditions should be regarded as a proof of its efficiency.

As a rule the internal resistance of Dynamo-Electric Machines is so low that to replace them by a battery, the latter, to possess an equal internal resistance, would have to be made of very large dimensions, so that the efficiency of Dynamo-Electric Machines cannot be stated in terms of battery cells as ordinarily constructed.

In regard to the second division, viz., the external work of the machine, this may be applied in the production of light, heat, electrolysis, magnetism, etc.

Where it is desired to produce light, the external resistance is generally that of an arc formed between two carbon electrodes; the resistance of the arc is therefore an important factor in determining the efficiency. To realize the greatest economy, the resistance of the arc should be low, but nevertheless should constitute the greater part of the entire circuit resistance.

In some of our measurements the resistance of the arc was surprisingly low, being in one instance ·54 ohm., and in another ·79 ohm. It was however in some instances as high as 3·18 ohms.

It may be noted, as an interesting fact, that where the greatest current was flowing, the resistance of the arc thereby produced was low. This is undoubtedly due to higher temperature and increased vaporization from the carbons. In this latter case also the greatest amount of light was produced.

The amount of work appearing in the arc as measured by the number of foot pounds equivalent thereto, is not necessarily an index of the lighting power. In two instances of measurement, the amount of energy thus appearing in the arc was equal, while the lighting powers were proportionately as three to four. This apparent anomaly is explained by considering the resistance of the arc, it being much less in the case in which the greater light was produced. The heat in this case being evolved in less space, the temperature of the carbons and therefore their light-giving powers, was considerably increased.

A few remarks on the economical production of light from electrical current may not be out of place. The light emitted by an incandescent solid will increase as its temperature is increased. In the voltaic arc the limit to increase of temperature is in the too rapid vaporization of the carbon. Before this point is reached, however, the temperature is such that the light emitted is exceedingly intense. No reliable method of measuring the temperature of the arc has as yet been found.

A well known method of obtaining light from electrical currents is by constructing a resistance of some material such as platinum having a high fusing point and heated to incandescence by the passage of a current. When platinum is employed the limit to its increase of temperature is the fusing point of the platinum, which is unquestionably but a fraction of the temperature required to vaporize carbon. Were the falling off in the amount of light emitted merely proportional to the decrease in temperature, the method last described might be economical. Unfortunately however for this method, many facts show that the decrease in the light emitted is far greater than the decrease of the temperature. Most solids may be heated to 1000°F., without practically emitting light. At 2000°F., the light emitted is such that the body is said to be a bright red. At 4000°F., the amount of light will have increased more than twice, probably as much as four times that emitted at 2000°F. It is reasonable to suppose that with a further increase of temperature, the same ratio of increase will be observed, the proportionate increase in luminous intensity far exceeding the increase in temperature.

It would therefore appear that the employment of a resistance of platinum or other similar substance, whose temperature of alteration of state as compared with that of carbon is low, must be far less economical than the employment of the arc itself, which as now produced has been estimated as about two or three times less expensive than gas.

Indeed it would seem that future improvements in obtaining light from electrical currents will rather be by the use of a sufficient resistance in the most limited space practicable, thereby obtaining in such space the highest possible temperature.

Perhaps the highest estimate that can be given of the efficiency of Dynamo-Electric-Machines as ordinarily used, is not over 50 per cent., our measurements have not given more than 38 per cent. Future improvements may increase this proportion. Since the efficiency of an ordinary steam engine and boiler in utilizing the heat of the fuel is probably overestimated at 20 per cent., the apparent maximum percentage of heat that could be recovered from the current developed in a Dynamo-Electric-Machine would be overestimated at 10 per cent. The economical heating of buildings by means of electricity may therefore be regarded as totally impracticable.

Attention has, long ago, been directed to the use of Dynamo-Electric Machines for the conveyance of power. Their employment for this purpose would indeed seem to be quite promising. Since in this case one machine is employed to produce electrical currents, to be reconverted into mechanical force by another machine, the question of economy rests in the perfection of the machines and in their relative resistances.

In respect to the relations that should exist between the external and internal work of Dynamo-Electric Machines, it will be found that the greatest efficiency will, of course, exist where the external work is much greater than the internal work, and this will be proportionately greater as the external resistance is greater. Our measurements gave in one instance the relation of ·82 ohm. of the arc to ·49 ohm. of the machine, a condition which indicates economy in working. The other extreme was found in an instance where the resistance of the arc was 1·93 ohm., while that of the machine was 4·60 ohms., a condition indicating wastefulness of power.

Nickel Compass Needles.—Joseph Wharton has sent to the French Academy a marine compass with a nickel needle, constructed nearly after Sir Wm. Thomson's model. Four similar compasses have been placed on Russian cruisers. It is proposed that the fifth should be put on a French ship for comparison with steel needles.—*Comptes Rendus.*

PHOTOGRAPHY AS APPLIED TO THE REPRODUCTION OF PLANS AND DRAWINGS.

By David Townsend, B. S.

The various means by which drawings may be copied without the aid of a camera will, I think, be of interest to all, but more especially to draughtsmen and engineers whose time is valuable and whose dislike to making intricate tracings, proverbial. The different processes, which I will describe in detail, were all practiced in my laboratory with a view to the adoption of the best by the works with which I am connected. I write, therefore, to benefit those who may be already on the road or who wish to follow after. But, before passing to details, it would be well to consider the substances used as sensitizers, or picture producers, and the effect which light has upon them. This will enable us to better understand the chemistry of the processes and perhaps point the way to new fields and improvements. The compounds most used to make a sensitive paper are chloride of silver, the persalts of iron and uranium, and bi-chromate of potassium. These will be considered, with regard to the changes produced on them by light, in the order named.

Chloride of Silver.

Chloride of silver was the first substance noticed that changed by exposure to light. Its properties were known to the alchemists of the sixteenth century, who called it "*lua cornua*," but it was first brought to notice by the researches of Scheele in 1778. This celebrated chemist observed that whenever chloride of silver was exposed to light, chlorine was liberated, producing a blackening, and that on treating this black residue with ammonia, metallic silver was left behind. The present theory is that the chloride is reduced to the state of sub-chloride by the action of light and free chlorine is liberated. It was also observed that when silver chloride was exposed in the presence of nitrate of silver the blackening was much more rapid, owing to the fact that the free chlorine liberated united with the silver nitrate to produce fresh silver chloride. Thus we conclude that the sensitiveness is increased in proportion as there is a chlorine absorbent present. If, then, we sensitize a piece of paper, that has previously been salted, with nitrate of silver in solution, the sodium chloride will precipitate some of the silver as chloride while the excess will still remain as nitrate, thus making a highly sensitive surface and fulfilling all that is required for printing pictures.

IRON AND URANIUM.

The next salts we shall consider, in regard to their behavior when exposed to light, are those of iron and uranium. Their reactions are similar, and we are indebted to Sir John Herschel and Niepce de St. Victor for the discovery of their peculiar properties. If we take two pieces of paper and brush them with a solution of ferric chloride, then expose one to the light and retain the other, finally flow ferricyanide of potassium over both we will find that the one that was exposed will turn blue, while the other will remain unaltered. Now, as ferricyanide of potassium precipitates iron only in the *ferrous* state, we conclude that the action of light has been to reduce the ferric chloride (Fe_2Cl_6) to ferrous chloride ($FeCl_2$). By similar experiments we may say that the action of light on all ferric salts, under certain conditions, is to reduce them to the ferrous state. The conditions to which I refer are the presence of some organic matter, such as the paper, glazing, etc., because otherwise the reduction is exceedingly slow. This property of reduction by light possessed by all per-salts of iron should be especially remembered, as it forms the basis of a number of processes whose details will be given hereafter. The action of light on the per-salts of uranium, especially the nitrate, is exactly similar to its action on iron, it reduces all uranic to uranous compounds.

CHROMIUM.

The remaining metallic compounds which are of value as sensitizing agents are those of chromium combined with the alkalies. The alkaline bichromates, and especially of potassium are, under certain conditions, far more sensitive to the action of light than either nitrate or chloride of silver. Potassium bi-chromate ($K_2Cr_2O_7$) by itself is a permanent salt, but when in contact with organic substances, it quickly decomposes in the light. This property and its extreme sensitiveness renders it invaluable to photography, in which it forms the basis for numerous processes, such as the Carbon, Woodbury, Photolithographic, etc. It is also the principal ingredient in the aniline process, at present much used in Europe for the reproduction of drawings.

Having thus seen the action which light produces on the different substances, we will now consider how we can best use their peculiar properties for producing photographic pictures. It would be well to mention here that in *all* cases, whatever the process, the operations of producing a picture are substantially the same. First, there must be a suitable support, or ground on which the picture is to be produced, such as paper; second, the ground must be coated with substances, called sensitizers, which shall be sensitively affected by the light; third, chemical reagents must be used which will combine with and develop the image produced upon the sensitive paper, and, fourth, fixing agents or chemical solvents must be used that will dissolve all unaltered sensitizing agents and make the picture permanent. Let us now consider the different processes.

SILVER PROCESS.

As was stated before, Scheele was the first to point out the effect which light had on chloride of silver, but Sir Humphry Davy, in 1802, was the first to produce a picture by the silver process; since that time it has made rapid strides toward perfection and it is to-day the only printing process that has taken firm hold on practice. Of all the processes which I shall give, it is the most reliable, the easiest to govern, and yields the best results. The manipulations required are more numerous than difficult, and after a little practice, become as easy as simpler methods. The operations taken in their order are as follows:—

1. Preparing the paper, or salting.
2. Sensitizing.
3. Exposing.
4. Washing.
5. Toning.
6. Washing.
7. Fixing.
8. Final washing.

(1) *Salting the Paper.*

As the plain salted paper, which is invariably used for this process, is easily obtainable in the markets in sheets of any size, it is not necessary that time should be consumed in its preparation; but for those who are not convenient to any depot, or who wish to prepare it for themselves, the following directions will be of value. The papers most preferred are the Rive and Steinbach, but other brands of English and American manufacture will answer just as well for this purpose. If the paper be of the finest quality imported the salting solution is composed of

Ammonium chloride,	1 part.
Pure water,	46 "

but if it be the ordinary market article, or has not sufficient sizing, the solution should contain:

Sodium chloride, ...	4 parts.
Ammonium chloride, . . .	6 "
Sodic citrate, ...	10 "
Gelatine, ...	1 "
Pure water, ...	460 "

Sufficient of the solution must be made to cover the bottom of a pan to the depth of half an inch. The pan should be two inches larger each way than the sheet to be salted and may be made of wood or tin, properly protected. It would be well to state here that all the pans, with the exception of the silver bath, can be made of tin thickly coated on both sides with asphalt, which renders them impervious to acids and alkalies. These pans should be made of a size to suit the largest drawing to be copied, and each operation should have a pan especially for that purpose. The salting bath is now poured into a pan, and all bubbles removed from the surface with a piece of paper, the paper to be salted is then taken between the thumb and first finger of each hand, at opposite corners, and curved so that on letting it down until in contact with the liquid, the centre line will touch first. The right hand is lowered carefully, and then the left, until the paper floats evenly upon the surface of the solution. If any air bubbles are observed under the sheet, one corner is lifted and the bubbles touched with a glass rod. This is very important, otherwise the air, acting as a cushion, prevents the salting solution from touching the paper and leaves a spot which will not become sensitive in the next operation. After allowing to float three or four minutes, the paper is raised by lifting two corners on the short side and drawing it evenly from the bath, after which it is suspended from a line by compression pins and allowed to dry. The process of swimming the paper, as described above, is also applied when sensitizing, and should be practiced until perfection is attained. Care must be exercised in both operations not to allow the solution to flow on the back of the paper, as a black spot will be the result when it is exposed to the light. When the paper is dry, it is taken from the line, stamped or marked on the *back*, and laid away flat, to be used as needed. A description of the preparation of albumen paper is not necessary, as it is seldom used for reproductions and can be bought much cheaper than one could make it. For copying very fine engravings or architectural designs, it is sometimes desirable because of the brilliant finish and the pleasant color when toned.

(2) *Sensitizing.*

We now come to the second operation, namely, sensitizing, or applying a substance which will be affected by the light. In this case, we use nitrate of silver, the theory being that when the salt in the paper comes in contact with a solution containing the nitrate, chloride of silver is precipitated, which forms an exceedingly sensitive surface, in the presence of an excess of nitrate of silver and organic matter.

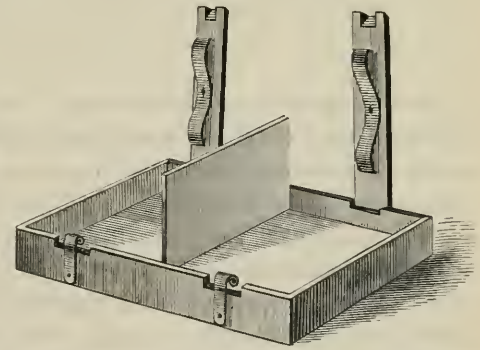
The silver bath consists of:—

Cryst. silver nitrate, ...	1 part.
Citric acid, ...	½ "
Alcohol, ...	1 "
Distilled water, ...	10 "

The pure crystallized nitrate of silver is dissolved in one portion of the water, the citric acid in another, and the solutions added, together with the alcohol. Paper sensitized with this bath will keep unaltered for months, whereas, if only nitrate of silver and water had been used, it would turn yellow in a short time. Enough of the bath should be made up to float the paper without touching the bottom of the pan. The vessel in which the sensitizing is performed consists of a tin pan, thickly painted with asphalt, which, when dry, is coated by means of a brush with melted wax. This, when cold, forms a good lining which is not in the least affected by the silver and which does not affect or contaminate it. I have used such a pan for months without any perceptible change in either the pan or bath. This forms a cheap and desirable substitute for porcelain, which would be difficult to get sufficiently large. The manipulation of the paper is the same as described under the head of salting, being shortly as follows:—The paper is taken at two opposite corners and bent evenly without making any creases or breaks. It is then held over the bath and lowered gently until it touches the liquid. One corner is then lowered until half the paper lies on the bath, then the other is treated likewise The paper should always be rolled with the salted side out, otherwise the edges will dip into the bath on floating it, and cause spots on the back. When the paper is very large it is necessary to have an assistant to prepare it properly. If any bubbles appear under the paper, they must be carefully removed with a glass rod, but when the sheets are large it will be more convenient to touch the spots with a clean brush moistened with the solution, on taking the paper off the bath. The paper is allowed to float for one minute in winter and forty to forty-five seconds in summer. The temperature of the bath is also important, because if it be ice-cold sensitizing will proceed very slowly, therefore it is best to warm the liquid slightly in very cold weather. The paper is just the opposite, as it keeps best when cold. Sensitizing should be performed in a dark room, photographically speaking; that is, in a room lighted only by such colors as have no actinic action on sensitive substances, such as red, orange, or yellow. My own laboratory is arranged with heavy yellow shades, put on rollers which slide in grooves, thus I can have actinic or non-actinic light at pleasure by simply raising or lowering the shades. It would be well to have such an arrangement, as all the operations to the final washing require to be performed in non-actinic light. Care should be taken not to let the silver solution wet the back of the paper, and to avoid touching it with unclean fingers, as black spots will appear when the sheet is exposed, and mar the beauty of the drawing. When the paper is sufficiently sensitized, it is drawn carefully from the bath, and suspended from a line by compression pins, to dry. A piece of blotting paper should be placed under it to catch the silver solution which drops off and which may be regained. The silver bath should be occasionally tested for strength, and, if weak, the proper amount of new nitrate added. It may also become cloudy, due to organic matter, but this may be removed by adding a few drops of potassium permanganate in water (1 to 100) or until a faint pink color is produced, then putting it in the sunlight for several hours. Silver stains on the hands may be removed by rubbing them with cyanide of potassium and water, but as this salt is a deadly poison it should be used with great care.

(3) *Exposing.*

Next is the exposing of the prepared sensitive paper to the action of light, under a drawing in order to produce a copy. The theory of the operation has been explained; it is carried out in what is known as the printing frame (Fig. 1). This consists of a wooden box having four shallow sides, two to four inches in height, the front being a piece of plate glass, fitting in the frame, and the back (C) consisting of two pieces provided with hinges so that either side may be opened without disturbing the other. The back is pressed tightly against the glass by means of a couple of springs (A and B) fastened on two cross pieces of wood held by catches and hinges to the frame. To the back is glued a soft piece of canton flannel which presses against the glass. These frames may be procured ready made from 3 × 4 inches up to 20 × 24 inches, and other sizes may be had to order. The frame is carried into the dark room, the back removed, and the drawing, if on tracing paper, is put in with its right side against the glass; the sheet of prepared paper is then placed with its sensitive side against the back of the drawing; two or three thicknesses of canton flannel are next laid in and then, after making all as smooth as possible, the back is replaced and the springs shut. If, on turning it over, any wrinkles appear, that side of the frame is re-opened and a piece of paper put against the spot, when all will come smooth on again closing the frame. The frame is now carried into the light and left until the paper turns brown, which it will do in a short time. It is then carried back and opened or, if not in sunlight, it may be quickly examined without taking it to the dark room. If all the lines are still white, it must be closed and again exposed to light, but if the white lines are slightly brown, the exposure is sufficient. In every case the print should be over exposed, as it fades considerably in the subsequent operations.



No special directions need be given in regard to time, as it varies considerably and is, besides, easily controlled. The picture produced will be a positive, or like the original, except it will have white lines on a dark ground. In order to produce dark lines on a white ground, two prints are required to be made, one reversed, which is finished and then used as a negative to produce the desired positive. Drawings made on tracing cloth may be printed either as positive or negative at will, but where the original is on regular drawing paper, a negative only can be produced, owing to the thickness of the paper. Originals made on paper that is soiled, or yellow from age, can not be copied because the color makes them non-actinic. It would be well to remember that the more opaque the lines of the original, the better will be the copy, therefore we make use of the non-actinic properties of certain colors and mix brown, vermillion, or yellow with the India ink used in making the drawing. It is a good plan in large establishments, where a great many copies of one drawing are required, to pencil the original on paper and finish only the tracing which may be kept as a negative to reprodúce any number of copies. My own experience has been that tracing cloth is much better than paper, as it is less liable to tear or wrinkle and gives more accurate results.

(4) *Washing.*

After obtaining a sufficient exposure, as directed above, the frame is brought into the dark room and the picture removed; it is then put in a pan of sufficient size, arranged so that water may run in at one side and out at the other, and left until the water becomes clear. If this cannot be conveniently accomplished, it is placed in a pan and the water changed four times. Now, as all the parts protected from the light still contain nitrate of silver, this will be dissolved in the water and it becomes a matter of economy to recover it. When the print is small, the water may be preserved in a keg and the silver extracted at leisure, but where running water is used, other means must be resorted to. The easiest way is to place two old felt hats, each containing a handful of common salt, under the exit pipe, when the silver in passing through the salt will be precipitated as chloride and caught in the fibers of the felt. In the course of time the hats will become saturated and may then be dried, burned, and the silver extracted. The next two operations, viz., (5) Toning and (6) Washing, are seldom performed for copying drawings, but the print is immediately fixed after being washed. For very fine line engravings, or for copying photographs, they are important, and so I will describe them.

(5) *Toning.*

By toning we mean giving color or tone to the picture. The chemical theory is somewhat complicated but depends principally upon the fact that when a neutral solution of some metallic chloride, such as gold or platinum, comes in contact with the washed print the chlorine leaves the gold and combines with the silver, thus forming a deposit of gold on the picture. The chloride of gold is generally used for this purpose and a normal solution is made by dissolving

Chloride of gold and sodium,	1	part.
In dist. water,	50	"

This is kept in a bottle and for every sheet of 20 × 24 inches 3 cc. are taken and mixed with 300 cc. of the following solution:—

Borax,	1	part.
Water,	150	"

It is sometimes convenient to keep a toning bath made up which can be used a number of times; in this case it should consist of:—

Chloride of gold,	1	part.
Chloride of calcium,	1·4	"
Water,	4,564	"

A little gold should be added from time to time, as the bath becomes exhausted. As nothing but small prints will require toning, a suitable porcelain dish should be provided and kept solely for this purpose.

(6) *Washing.*

This washing is merely to remove surplus toning solution and is not very important. Five minutes in running water will be sufficient, and the waste need not be saved as it is too dilute to pay for the trouble of extracting the silver.

(7) *Fixing.*

After removing all metallic salts, soluble in water, by washing, it is next necessary to dissolve out those still insoluble and remaining in the parts unacted upon, so that when the picture is finished and brought into the light,no change will take place. The solvent generally used is hyposulphite of sodium, or "hypo" solution, as it is technically termed.

This salt has a peculiarity which should be remembered, namely, when in excess it acts as a solvent for salts of silver, but when the latter are in excess, the silver is precipitated as sulphide which, when in contact with the paper, becomes black and insoluble. Great care must therefore be taken to have the hands perfectly free from "hypo," when silvering the paper or in afterwards handling it, otherwise black spots and finger marks will be produced. The fixing bath consists of:

a.	Hyposulphite of soda ($Na_2S_2O_3$),	1	part.
	Water,	10	"
	Concentrated ammonia,	$\frac{1}{6}$	"

or

b.	Saturated solution of hyposulphite,	1	part.
	Water,	8	"
	Saturated solution bicarbonate of soda,	$\frac{1}{4}$	"

The alkali in both cases is used to neutralize any free acid in the solution which would otherwise liberate sulphur and produce black spots on the print. I think formula (*b*) is preferable to formula (*a*), because the ammonium in the latter causes the paper to become very tender and it is much more easily torn. The solution is put in a pan kept especially for the purpose, and the washed print transferred by taking two corners and lifting it carefully from the surface of the water. It is then let down as quickly as possible and speedily covered on all parts with the fixing solution, being careful to remove all bubbles. It is allowed to remain completely immersed for eight to ten minutes in warm weather, but if the bath is cold, a much longer time will be required. When the paper looks transparent the fixing is finished. The prints fade considerably in this bath, but regain some of their color when washed and dried. The fixing solution must now be removed from the paper or it will dissolve the image, and this is accomplished by the last operation to which the paper is subjected, namely—

(8) *Final Washing.*

The print, which is now very tender, is taken by the two shortest corners and raised off the fixing bath; it is allowed to drain thus for a short time, and is then carried to a pan kept especially for this purpose. The thoroughness with which this washing is performed will determine the durability of the picture. The prints cannot be washed too long, it being customary in photographic establishments to leave them in water all night; but for drawings, if the water be *completely* changed eight or ten times, it will suffice. In any case, let them be washed as long as the time will allow. The print is then removed and pressed between blotting papers, which absorb all the surface moisture and make the print much lighter. It is now carried into a light room, free from dust, suspended from a line by spring clips, and left until dry. Care must be taken not to tear the paper, and thus spoil the work. When dry, the print is removed and trimmed, and is considered finished. The pieces of paper and trimmings should be preserved, as they contain silver, which may be extracted, or sold to dealers, who give nitrate of silver in return.

I have described this process at some length, believing it the best that can be adopted. It has numerous advantages, which will recommend themselves to all having much copying work to do. It is true, first cost is against it, but the results, especially for large work, are the best that can be obtained from any of the processes. We will now pass on to other methods.

IRON.

Next in importance to the salts of silver, come those of iron, and their reactions furnish us with numerous methods for reproducing drawings. The compounds of iron most used are certain double salts, such as citrate of iron and ammonia, oxalate of iron and potassium, tartrate of iron and ammonium, and, of the single salts, the oxalate and per-chloride. In every case the iron must be in the ferric state, otherwise no reduction will occur, and consequently no picture will be produced. All the processes depend upon the reactions of ferro- and ferri-cyanide of potassium on the salts of iron, as already explained. The only thing we have to consider, then, in choosing a salt for a sensitizer is, which one will be the most sensitive to light, and can be procured cheapest. There are two processes which may be considered as typical, the first being called

PELLET'S PROCESS.

This was invented by H. Pellet, of Paris, and is quite recent. It gives a blue picture on a white ground, the operations being as follows:

The best quality of paper must be used, or the per-chloride of iron which is used to sensitize it will soak through, making very ugly spots on the back when developed. If the paper is not sufficiently glazed, liquid gum or gelatine should be added to the sensitizing bath. I obtained the best results in my experiments by using albumenized paper such as is used in portrait photography. The paper is cut to suit the drawing, which for this process must be on tracing cloth, and is then sensitized by floating it, as before described, on a bath composed of

Per-chloride of iron, ...	10 parts.
Water, ...	100 "
Citric or tartaric acid, ...	5 "

The sensitizing must be performed in a dark room and the solution always excluded from the light. The paper is allowed to remain on the bath for thirty seconds, when it is carefully removed and hung in a warm place to dry. It can then be used immediately or preserved unchanged in a dark place. The tracing to be copied is placed in a printing frame together with a sensitive sheet of paper, and is then taken into the light. In sunlight, from fifteen to forty seconds will be sufficient to reduce all the iron to the state of proto-chloride, except such parts as are protected by the black lines which will still remain in the ferric state. If the day be cloudy, from fifteen to twenty minutes will be necessary to complete the reduction. The time of exposure can be determined by a few experiments, as it will vary considerably with the time of the year, the light being twice as strong in summer as in winter. When the exposure is complete, the frame is brought back into the dark room and opened, when a faint image will be observed on a deep orange-yellow ground. The paper is now plunged into a bath containing

Yellow prussiate of potash (K_4FeCy_6), . .	24 parts.
Water, ...	100 "

When a blue image will appear on a white or blueish ground, if the development is sufficiently prolonged. The parts protected by the black lines being still in the ferric state will be precipitated by the ferrocyanide as prussian blue [$Fe_4(FeCy_6)_3$] while the unprotected parts, being reduced to the ferrous state, will form a *white* precipitate which absorbs oxygen from the air and speedily turns blue if not removed. If the exposure has been too short, all the per-chloride will not be reduced and blue spots will appear on the ground, but if too long, the image itself will be somewhat faint, owing to a partial reduction under the lines, and will require an exceedingly long development. When the image is sufficiently developed, the print is removed and washed in an abundance of clean water, to remove the white precipitate, after which it is put for a few minutes in a bath of

Hydrochloric acid,	1	part.
Water,	10	"

which will deepen the blue picture and whiten the background. After washing for some time, the print can be dried and are then finished. This process is hardly applicable on a large scale, as it requires such care and nicety of execution to attain desirable results, that it could not be trusted to any but experienced hands. If the paper, after exposure, had been put in a bath of

Red prussiate of potash ($K_6Fe_2Cy_{12}$),	25	parts.
Water,	100	"

a reversed picture would have been obtained, having white lines on a blue ground, owing to the fact that the unprotected parts being reduced to the ferrous state, would be precipitated by the ferricyanide as Turnbull's blue ($Fe_3Fe_2Cy_{12}$), while the protected lines would remain unchanged, so that when washed in water the per-chloride would be dissolved, giving white lines on a blue ground which would be further intensified by the acid bath. The name of cynotype was given to the latter process by its discoverer, Sir John Herschel. He also developed, on a dilute neutral solution of gold, tri-chloride getting a purple picture to which he gave the name of chrysotype. Any other per-salt of iron could be used as a sensitizer and developed on the ferrocyanide bath with the same result.

Blue Process.

The process which is most used in America, and which has been largely adopted by our manufacturers, is known as the blue process. The drawings are reproduced in white lines on a blue ground, and I understand the paper is sold in the market already sensitized, although it can be prepared cheaper and just as well as the bought article. Almost any heavy well-glazed printing paper will answer the purpose, but, as this is the only expense, a good quality should be used. The sensitizing bath consists of

a.	Citrate of iron and ammonia,	1	part.
	Clear water,	4	"
b.	Red prussiate of potash,	1	"
	Water,	6	"

The two solutions are dissolved separately, and preferably at the ordinary temperature; when in complete solution they are mixed, and kept in a yellow bottle, or carefully excluded from the light, which would cause a blue precipitate. If the paper is not sufficiently sized, gum or gelatine should be added to give it body and prevent the liquid from soaking through. The sensitizing is performed as follows, in non-actinic light: The sheet of paper, cut to the required size, is pinned to a clean board; some of the solution is poured into a vessel, and the paper painted with it by means of a soft camel's hair brush three inches wide. The brush is dipped into the solution and the paper completely moistened in one direction; then, without removing the liquid, it is smoothed until no streaks or lines appear. Some prefer to use a sponge, but this causes uneven spots, and mars the beauty of the picture. In this way a very little solution will cover quite a large surface. Before putting the brush away it must be carefully cleaned. The paper is unpinned, hung upon a line, and when dry will keep a long time in the dark. It should be a brass-yellow color when rightly prepared. To make a copy, the drawing, on tracing cloth, is put into the printing frame, as usual, with a sensitive sheet, and exposed to sun light for six to ten minutes, or to diffused light for one to two hours. The double salt is reduced to the ferrous state where the light strikes it and immediately combines with the red prussiate present, to form Turnbull's blue, while the protected parts remain unchanged. The exposure should be continued, until, on opening the frame, the white lines have almost disappeared and the back ground is grayish-green. The sheet may also be exposed on a board padded with flannel, over which is placed a sheet of plate glass, but this requires to be always horizontal, and needs more apparatus than it would cost to get a regular frame. When exposure is finished the print is removed, and put immediately into a tank of running water, when the lines will become white (unless over-exposed or not in contact), while the ground becomes dark blue. After sufficient washing, the ground can be improved by transferring to a bath of

Hydrochloric acid, ...	5 parts.
Water, ...	100 "

when it must be again thoroughly washed, and then dried. The color always darkens on drying, and prints that would otherwise be under-exposed have very beautiful light blue ground.

This process has become the favorite one, owing to its great simplicity, and the ease with which any one can work it; the objections to it are: the length of exposure, especially on cloudy days, and the impossibility of copying drawings from anything but tracing cloth or paper. In very large sheets the fine lines are apt to be reduced, thus making the picture somewhat uncertain in parts. If, instead of mixing the solutions, the paper had been sensitized with the citrate bath and then exposed, the reduction would have been very rapid (fifteen or thirty seconds), as this is the most sensitive salt of iron. The picture could then be developed in the ferricyanide bath, and finished as described; but in this case it is better to sacrifice sensitiveness to convenience. The other double salts could be used to replace the citrate, but they require a longer exposure.

URANIUM.

The salts of uranium are affected similarly to those of iron, but they offer no advantages over the iron salts, and are besides very expensive. Those who desire to try them may use the following formulas.

A good quality of paper must be taken and sensitized by floating for six or eight minutes on a solution of

Uranic nitrate, ...	1 part.
Dist. water, ...	60 "

When dry the paper is exposed under a drawing for ten or fifteen minutes, and is then removed and developed by floating on

Ferricyanide of potassium, . . .	1 part.
Water, ...	250 "
Nitric acid, ...	2 drops.

In about five minutes a brown picture will appear, which is fixed by washing in slightly acidulated water.

To produce a gray picture the print is floated on a bath of

Silver nitrate, ...	1 part.
Water, ...	20 "
Acetic acid, ...	a trace.

The development is very rapid in this solution, being complete in thirty seconds, after which it must be taken out and thoroughly washed in clean water. Red, green or violet pictures may also be produced, by developing on ferrocyanide of potassium, perchloride of iron, or chloride of gold.

CHROMIUM.

The fourth and last salts are those of chromium, only two of which are commonly used, namely, the bi-chromates of potassium and ammonium. These form the basis for a number of valuable processes, one of which is at present attracting much attention in Germany, where it has been carried to a high state of perfection in the reproduction of drawings and fine engravings. It is called the

ANILINE PROCESS.

This was invented by Mr. Willis in 1864. It depends on the fact that when potassium bi-chromate, in the presence of organic matter, is exposed to the action of light, free chromic acid is formed and the protected parts, which still remain as bichromate, form aniline colors when exposed to the vapors of aniline salts. The process, in detail, consists of the following operations:

(1) Sensitizing the paper.
(2) Exposing.
(3) Fuming.
(4) Washing.

(1) *Sensitizing.*

The best Saxe paper must be used, as no other will give satisfactory results. The sensitizing solution consists of

Potassium bi-chromate, ...	1 part.
Phosphoric acid, sp. gr. 1·124, .	8 to 10 "
Distilled water, ...	10 " 12 "

The paper, after being cut and the finest side selected for use, is pinned to a clean, flat board. Some of the solution is poured into a dish and the paper is sensitized by means of a stiff brush, about one inch wide, which is dipped into the liquid and then painted on the paper, first lengthwise and afterwards across, without renewing the liquid on the brush. Finally, a soft camel's-hair brush, about three inches wide, is used to remove all superfluous liquid, and smooth out any streaks left by the first brushing. The solution may also be applied with a soft sponge, but the first method is preferable as the fingers are not then brought into contact with the bi-chromate which is a violent poison. The sheet is now hung up and allowed to dry slowly, it being complete in from fifteen to twenty minutes. The operation should be performed in a dark room lighted with a lamp having a yellow chimney. Ordinary yellow light is not sufficiently non-actinic, owing to the extreme sensitiveness of the paper, which is easily affected by the least light. When dry, it may be preserved for some time unaltered in the dark. The brushes should be thoroughly washed each time they are used, and carefully protected from dirt.

(2) *Exposing.*

The prepared paper is now placed in the printing frame, under the tracing, covered with a black cloth and carried into the sunlight. The length of exposure will vary with the time of the year; in summer, being about twenty seconds, and in winter, forty seconds. The surest method is to use Vogel's photometer and carry the exposure to sixteen degrees, but as this cannot always be obtained, experiments may be made to determine it. This is the most important part of the whole process, because undue exposure will not reduce the bi-chromate sufficiently, and over exposure renders the paper less liable to form aniline colors. When the paper is rightly prepared, it should be a light yellow color and after exposure, on opening the frame, a faint yellow picture will be observed on a greenish ground.

(3) *Fuming.*

When the exposure is judged sufficient, the cloth is replaced and the frame carried back into the dark-room, where it is opened, the picture removed, and pinned to the lid of a fuming box. The box is provided with a sheet of glass, on which is blotting paper soaked with a solution of

Aniline oil, ...	1 part.
Benzine, ...	10 "

and which can be lowered or raised at pleasure by means of cross pieces of wood at different heights. It is allowed to remain thirty minutes, when the picture, if rightly exposed, will be sufficiently developed and will show a dark brown or purple picture on a gray ground. If the image is rather faint, it should be fumed longer.

(4) *Washing.*

On taking out the print, it must be washed for some time in at least four changes of water, when the colors will be fast, and, after drying, the picture is finished. Great care must be taken not to handle the sensitive paper any more than is absolutely necessary, and then only with perfectly clean hands; also to perform *all* the operations in absolutely non-actinic light.

In review, we conclude that, in point of cheapness, the blue process has the preference; but, for certainty of results and general reliability, under all conditions, the silver process is the best. I should, therefore, recommend it in all cases where first cost will not be a consideration compared to convenience and saving of time.

Jan. 2, 1879.

ADDENDA TO A PAPER*—"COAL GAS ENGINEERING."

The following summary of the relations of constituents of coal gas may prove useful for reference in many instances:

Table of percentages, by weight, of the Constituents of Coal Gas.

			H, Hydrogen.	C, Carbon.	O, Oxygen.	N, Nitrogen.
H	Hydrogen,	= 7·3171	= 7·3171			
CH_4	Marsh gas,	= 47·2861	=11·8215	=35·4646		
C_2H_4	Olefiant gas,	= 18·4407	= 3·0734	=15·3673		
CO	Carbonic oxide,	= 13·6331		= 5·8428	= 7·7903	
CO_2	Carbonic acid,	= 7·1620		= 1·9533	= 5·2087	
4N+O	Air,	= 4·6995			= 1·0443	=3·6552
H_2O	Vapor of water,	= 1·4615	= 0·1624		= 1·2991	
	Coal gas,	=100.	=22·3744	=58·6280	=15·3424	=3·6552

Table of weight of Constituents of 100 *cubic feet of Coal Gas in pounds and decimals.*

			H, Hydrogen.	C, Carbon.	O, Oxygen.	N, Nitrogen.
H	Hydrogen,	=0·23340	=0·23340			
CH_4	Marsh gas,	=1·50835	=0·37709	=1·13126		
C_2H_4	Olefiant gas,	=0·58823	=0·08403	=0·50420		
CO	Carbonic oxide,	=0·48488		=0·18638	=9·24850	
CO_2	Carbonic acid,	=0·22846		=0·06231	=0-16615	
4N+O	Air,	=0·14995			=0·03332	=0·11663
H_2O	Vapor of water,	=0·04662	=0·00518		=0·04144	
	Coal gas,	=3·18989	=0·69970	=1·88415	=0·48941	=0·11663

The table at the end of article on Coal Gas Engineering, in the June number of the JOURNAL of last year, should be corrected to obviate the errors in setting up:

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* JOURNAL OF THE FRANKLIN INSTITUTE for April, 1878, by Robt. Briggs, C. E.

Table of Relative Value of Standards used in Photometric Measurement.

One standard gas burner, per hour,	Total weight. lbs.	Ratios of weight of material consumed to give equal light.
equals 5 cu. ft. coal gas, of English quality =0·426 spec. grav.=0·0319 lbs. at 70°	0·1595	1·000
equals 15 standard candles, each burning 120 grains spermeceti = 0·09259 lbs.	0·2671	1·634
equals $\frac{15}{9{\cdot}6}$ = 1·5625 carcel lamps, each burning 42 grams=0·09259 lbs. colza oil	0·1447	0·908

A NEW CALORIMETER.

By W. L. Hooper, A.M.

There seem to me several objectionable points in the construction of the ordinary calorimeter: First, although the surfaces of the instrument are very poor radiators, the material of the walls is generally an excellent conductor; secondly, the air-space between the walls is entirely open so that much heat must be carried off by convection currents in the air. I have accordingly constructed an instrument in which both imperfections seem to be remedied. It consists of two ordinary glass beakers, one of which is placed inside of the other, supported by a rim of bright tin. Upon the outside of the inner beaker, and upon the inside of the outer, about four-fifths of the height from the bottom, a film of metallic silver is deposited by the ordinary process of silvering glass specula. It was hoped that this confined air-space, enclosed on *every* side by the very worst of radiators and absorbers, themselves non-conductors, would furnish an excellent barrier against the escape of heat from the liquid in the instrument. How far this hope was realized may be seen from the table below, in which the ordinary metallic calorimeter and my instrument are compared. The two instruments were placed side by side in a room free from draughts, and into each was poured 500 cc. of boiling water. The readings of a thermometer placed in each were then taken, the thermometer in my instrument being read just ten seconds before the other:

New Calorimeter.				Old Calorimeter.		
Time.				Time.		
h.	m.	sec.	Temp. °	h.	m.	Temp. °
3	2	50	93·4	3	3	93
3	5	50	88·7	3	6	85
3	7	50	86	3	8	81·3
3	9	50	83·5	3	10	78
3	11	50	81·1	3	12	75
3	13	50	79	3	14	72·5
3	15	50	77	3	16	70
3	17	50	75·1	3	18	68
3	19	50	73·1	3	20	66
3	24	50	69·2	3	25	61·8
3	34	50	64	3	35	55·4
3	54	50	55·3	3	55	46·7
4	9	50	50·2	4	10	43

It cannot be necessary to study the table very closely to observe the superiority of my instrument as a non-radiator. During the first three minutes, the water in the metallic calorimeter fell eight degrees in temperature; in the same time, the temperature in my calorimeter fell less than five degrees. Glancing down the columns, we find that while my instrument was parting with thirty degrees of heat, the temperature in the other had fallen nearly forty degrees.

While the new instrument has the disadvantage of being easily broken, it has the compensating advantage of being very easily made, whenever access may be had to a chemical or physical laboratory.

Bloomfield School, Harvard, Mass., Dec. 24, 1878.

Large Frost-Crystals.—At the meteorological observatory on the summit of the Puy-de-Dome, great difficulties are ofted experienced from the heavy deposits of hoar-frost. The telegraph wires often receive a coating of more than 20 cm. (7·87 inches) in thickness; the lightning rods have a much thicker covering, and on the windward side of the building ice-crystals sometimes form 85 cm. (33·47 inches) in length with their points toward the wind. Various plans have been tried to get rid of the inconvenience, but without success.—*La Nature.*

C.

Chemical Constitution of Wool.—P. Schützenberger has published analyses of various samples of wool, from which he deduces the chemical formula $C_{230}H_{381}N_{70}O_{77}S_6$.—*Comptes Rendus.* C.

Temperature of the Sun.—F. Rosetti has published the results of an extensive series of investigations, from which he estimates the temperature of the sun at between 12,000° and 20,000° (21,632 and 36,032°F.).—*Il Nuovo Cim.* C.

Metallic Packings.—J. Strieder, of Elberfeld, uses tubes of lead or some soft metallic alloy, filled with hemp, cotton or some other suitable vegetable material. These tubes can be prepared of great length and cut to fit any given requirement. The ends may be either soldered together or forced into close contact. The convenience, durability and cheapness of this packing are especial recommendations.—*Dingler's Pol. Jour.* C.

Pyrometers.—F. Fischer publishes the results of some comparisons of his small calorimeter with Steinle and Hartung's graphite-pyrometer, Siemens' electric pyrometer and Geissler's normal quicksilver thermometer. The instruments all agreed satisfactorily for temperatures below 450° (842°F.). Above that point Siemens and Fischer agreed, but the graphite indications were higher. When Siemens' marked 623° (1153°F.) the graphite gave 755° (1391°F.). The graphite, however, was more sensitive than the electric pyrometer.—*Dingler's Journal.* C.

Excavations and Foundations in Sand.—M. Plocq has published an interesting note upon the recent harbor improvements at Dunkerque and Gravelines. There are ten sluices for controlling the fresh and salt waters of the districts, for various purposes of maritime and domestic economy, as well as for the wants of the military service and for defensive operations in time of war. The sluices are built in a soil which is wholly made up of a pure sand, of flour-like fineness, reaching to a depth of 15 or 20 metres (16·4 to 21·9 yds.) below the lowest tidal levels. The works were all executed by the help of coffer dams, in preference to dredging, and the preparations were so thorough that it was always easy to work in dry sand even at the lowest foundation levels. The total cost was less than half what it would have been by the old method of dredging, and the saving of time was in about the same ratio.—*Ann. des Ponts et Chauss.* C.

New Electric Phenomenon.—About ten years ago, Govi found that the interior volume of a Leyden jar seemed to expand during a charge, and he attributed the phenomenon to a contraction of the liquid which it contained. Duter has now shown that the effect is due to a temporary expansion of the dielectric envelope.—*Comptes Rendus.* C.

New Mode of Cementing Metal to Glass.—Mix two parts of finely powdered litharge and one part of fine white lead; mix three parts of boiled linseed oil with one part of copal varnish; stir the powder into the liquid until it has the consistency of a stiff dough. Spread the cement on the metal, press it against the glass, and scrape off the surplus. It dries quickly and is remarkably tenacious.—*Fortschr. der Zeit.* C.

Spartan Soups.—Most persons have heard of the *black broth,* in which the Lacedemonians dipped their bread, and which they preferred to the most savory dishes. Meursius thinks that it was the water in which pork had been boiled, with the addition of vinegar and salt, the only seasonings which they employed. Ricard thinks it was a soup, and says that they made another kind with eels, which they called *white soup.—La Nature.* C.

Greenland Native Iron.—Prof. J. Lawrence Smith has presented a memoir to the French Academy upon the remarkable deposits of native iron in the basaltic beds of Greenland. After long study, he concludes that the iron is of terrestrial origin; that it is often so closely joined to the basalt that feldspathic and other crystals penetrate the iron, and that the iron is probably a secondary product formed by the decomposing action of lignite beds and other organic matters, which have been pierced by the immense basaltic dykes.—*Comptes Rendus.* C.

Giffard's Success.—Giffard made 1000 captive ascensions, on 72 days, taking 3,500 passengers, without the least accident, receiving 839,555 francs, distributing 35,000 commemorative medals at a cost of 44,000 francs, burning 150,000 kilogrammes (147·63 long tons) of coal under the boilers. He has solved some problems of great importance: the preservation of hydrogen for a long period in an impermeable tissue, the preparation of that gas on an enormous scale, the new construction of all the parts of a balloon on a plan which prepares the way for building true aerial ships.—*G. Tissandier.* C.

Earth Ventilation.—Fischer and Stiehl propose to draw air for ventilation through a system of tubes buried about 3 metres (9·84 ft.) in the ground. By this means the air would be warmed 8 or 9 degrees (14·4° or 16·2°F.) in winter and cooled 12 or 13° (26.6° or 23·4°F.) in summer.—*Dingler's Journal.* C.

Nitrous Oxide Under Pressure.—P. Bert finds that by placing a patient in an apparatus where the pressure can be increased to two atmospheres, nitrous oxide can be administered so as to produce continued anæsthesis, while the blood receives its normal supply of oxygen and the normal conditions of respiration are maintained. From various experiments on animals, he thinks that gas administered in this way will be harmless, however much the insensibility may be prolonged.—*Comptes Rendus.* C.

Trial of a Corliss Engine.—A commission for experimenting with an Alsatian-built Corliss engine, has made a report in which it concludes: (1) That in order to secure the best results, the engine should be worked to its maximum capacity. (2) The economy of the steam-jacket increases as the load diminishes. (3) The clearing of the jacket should be thorough, but without wasting steam. (4) The warming of the piston is sometimes economical, but the saving, in ordinary cases, is not sufficient to pay for the necessary complication of machinery. —*Bull. de la Soc. Ind.* C.

Saint-Gothard Tunnel.—The small bronze turbines, which make 155 million turns per annum, after four or five years' service, require but slight repairs. Turbines of iron and steel, under the same pressure, do not last over a year. The 16 air-compressors supply air enough, under a pressure of 8 atmospheres, to supply 18 to 20 drills and to ventilate thoroughly all the tunnel, of which about 8 miles has already been bored. On each side there are, night and day, many hundreds of workmen, as many lamps, and about 600 pounds of dynamite are used daily. The financial difficulties of the company are connected with other portions of the line. The works of the tunnel have not been interrupted a single day for six years, and the original estimates will probably not be exceeded, although many unforeseen obstacles have been encountered. The tunnel will probably be finished within eight years from its commencement. The stipulated time was nine years.—*Comptes Rendus.* C.

Vesuvian Railways.—Concessions have been granted to two rival companies for constructing railways to the summit of Vesuvius, and it is expected that both routes will be rapidly pushed to completion. In many places the sleepers will be supported by columns.—*Les Mondes.* C.

Indication of Water Level in Reservoirs.—M. Decondon, Engineer, Paris, has constructed a very ingenious apparatus for indicating, at any distance, the level of water in a reservoir. He places a bell-shaped casting, mouth downwards, in the reservoir, resting on the bottom and partially filled with air. At the top a tube leads to any convenient place, where it is connected with a manometer which is constructed similar to the aneroid barometer and which is so sensitive that it indicates the slightest difference between the water level in the bell and in the reservoir, owing to the pressure of the enclosed air, which will support a column of water equal to this difference. As the apparatus acts independently of the atmospheric pressure, there will be a slight error, equal to the height of the water column in the bell. But this may be greatly reduced by making the latter very large and flat.—*Wochenschrift Oest. Ing. and Arch't Vereins.* P.

New Plan for Filling Gas Meters.—The chemical laboratories of Jacobsohn and Brunje, at Leopold's Hall, near Stassfurt, Germany, have introduced a new fluid for filling wet gas meters, composed mainly of a solution of chloride of magnesium. The meter of the Royal Polytechnic Institute, at Hanover, was filled, Dec. 8th, 1877, with 142 litres of the same, of a spec. gr. of 1·201. By the 15th the contents had increased by 1·5 litres and the spec. gr. was 1·190. Examination at different dates showed that:

On Dec. 21, 1877, the spec. gr. was . 1·181
" Jan. 20, 1878, " " " . . 1·182
" Mar. 3, " " " " . 1·179
" June 1, " " " " . . 1·178
" July 15, " " " " . 1·174

On July 15th, 1878, the meter was opened and the solution analyzed. No trace of a foreign material (iron or tin) was found, but it contained in 100 cubic centimeters 0·0214 grammes of NH_3 (ammonia) abstracted from the passing gas. A portion of the solution was cooled to 10° without freezing. During the whole time no replenishing had been necessary.—*Journal für Gasbeleuchtung, etc.* P.

Franklin Institute.

HALL OF THE INSTITUTE, Jan. 15th, 1879.

The stated meeting was held at 8'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 174 members and 63 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 18 persons were elected members of the Institute, and reported also the following donations to the Library.

Annual Report of the Hartford Steam Boiler Inspection and Insurance Company, Dec. 31, 1877. Hartford, 1878.
From the Company.

Annual Report of the Secretary of the Interior for year ending June 30, 1878. Washington, 1878. From the Secretary.

Annual Report of the Treasurer of the United States to Secretary of Treasury for year ending June 30, 1878. From the Secretary.

Electric Constitution of our Solar System. By Jacob Ennis. Philadelphia, 1878.

Elements of Sidereal Astronomy. By Jacob Ennis. Philadelphia, 1878.

Physical and Mathematical Principles of the Nebular Theory. By Jacob Ennis. London, 1878.

Origin of Power which causes Stellar Radiations. By Jacob Ennis. London, 1878. From the Author.

Fifty-eighth Annual Report of the Managers of the Apprentices Library Company. Philadelphia, 1878. From the Company.

Proceedings of the Tenth and Eleventh Annual Conventions of the American Master Mechanics' Association, Cincinnati, 1877 and 1878.
From the Association.

Quarterly Weather Report of the Meteorological Office. Part 3. July—September, 1875. London, 1878.
From the Meteorological Office.

Minutes of Proceedings of the Institution of Civil Engineers. Vols. 53 and 54. London, 1878. From the Institution.

Third Annual Report of the Water Commissioners of the City of Lowell, 1873.

The President then presented and read the following

ANNUAL REPORT OF THE BOARD OF MANAGERS.

Your Board of Managers respectfully submits the following Report for the year 1878:

Members.—During the year 98 persons were elected members of the Institute, and 53 have resigned membership.

By death the Institute has lost four estimable life members, namely, Mr. Wm. Welsh, Mr. Bloomfield H. Moore, Mr. Thos. H. Powers and Mr. L. A. Godey.

Treasurer's Report.—The Treasurer's Report, which will be presented to the Institute this evening, exhibits the following summary:

Receipts.

Balance on hand Jan. 1st, 1878,		$1,809.48
Railway Equipment Bonds paid off,	$3,000.00	
Bloomfield Moore Fund held in trust for the improvement of the Library,	10,000.00	
		13,000.00
Receipts from ordinary sources of income,		9,710.11
		$24,519.59

Payments.

Bloomfield Moore Fund deposited,	$10,000.00
Payments for ordinary expenses,	11,501.42
Balance in hand Dec. 31, 1878,	3,018.17
	$24,519.59

It will thus be seen that the

Ordinary expenses were,	$11,501.42
" receipts,	9,710.11
Exhibiting a deficiency of	$ 1,791.31

which was occasioned by the continued defalcation in payment of the Bonds of the City of Pittsburg, and by other manifestations of the hardness of the times.

The Journal of the Institute has been issued regularly during the past year, under the direction of the Committee on Publication, with the assistance of the Secretary—an arrangement entered into in the early part of 1877, and which has proved very satisfactory.

The large number of articles containing the results of original work, by able investigators, which have appeared in its pages during the past year, have fully sustained its rank among the leading technological journals, as is evidenced by the amount of matter reprinted from it, both in home and foreign journals.

The deficit in its accounts for the past year was reduced to a comparatively small sum, and it is confidently hoped that with the continued assistance of its valued contributors, and the increased support of members and friends of the Institute, which will come with the revival of the industrial interest of the country, the JOURNAL will be entirely self-supporting.

Drawing School.—At the close of the spring term of the Drawing School, Prof. L. M. Haupt found himself compelled, by pressure of other duties, to resign its charge, greatly to the regret of the Board.

The school was reorganized, however, in the autumn by Mr. Philip Pistor, M. E., and there was instituted a regular course of instruction, extending over two years, commencing with the more important elementary problems in plane geometrical drawing, and covering so much of descriptive geometry and orthographic and isometric projection, as are necessary to a complete knowledge of mechanical, architectural and topographical drawing.

The instruction in free hand drawing was discontinued, except as applied to sketches of machines, etc., to be used in making scale drawing and some exercises in the different orders of architecture; leaving all the instruction of purely ornamental and decorative character to other well-known institutions in the city.

The method of teaching adopted omits almost entirely the use of flat copies, depending principally upon blackboard illustrations and exercises in drawing from models.

While this course was strongly recommended to all the pupils, those sufficiently advanced had the opportunity of electing to take special instruction in some branch of more immediate importance to themselves.

The results of the first quarter have been very satisfactory, nearly all the pupils choosing the regular course, and their advance has been very encouraging.

This is an important branch of the work of the Institute, and the Board commends it to the earnest support of the members.

Lectures.—During the early part of the year (Jan. 3d to March 5th) there were given six lectures by Prof. Elihu Thomson on the Correlation of Forces, three by Prof. P. E. Chase on the Manufacture of Bricks, Paper and Ink, and eight in the elementary series, by Prof. E. H. Bartley, on Chemistry.

In the arrangement for lectures this winter, there was provided a considerable number illustrating the useful applications of science, some of them being upon subjects now attracting a large degree of popular attention; of this class Prof. E. J. Houston delivered six during November and December.

During the same months Dr. W. H. Greene gave eight valuable lectures on Organic Chemistry.

The special rate of admission to the elementary lectures offered to non-members during the past two years was discontinued, as it was not made use of to any considerable extent.

Prof. Houston gave his usual lecture to children during Christmas week.

Phonography.—The class in phonography was continued under the charge of Mr. D. S. Holman, and the attendance during the year has been satisfactory.

Monthly Meetings.—The following statement of the attendance at the monthly meetings for the past three years shows a constantly increasing interest on the part of members and the public:

Years.	Members.	Visitors.
1876	1,060	112
1877	1,390	187
1878	1,425	400

Library.—The Board has been anxious for the improvement of the Library, and has appropriated to it all the funds available for that purpose, and beg to refer to the report of the Committee on its Condition, etc., which will be duly read.

By order of the Board,

R. E. Rogers, *President.*

After the reading, Dr. Rogers reminded the members that with this report he virtually ended his duties as President, and took occasion to thank them for their unvarying kindness toward him during the four years he had served the Institute, which, although old in years, is youthful in vigor and usefulness.

On motion of Mr. J. E. Mitchell, the order of business was suspended, and the following preamble and resolution were unanimously adopted:

WHEREAS, Our highly esteemed presiding officer, Dr. R. E. Rogers, having declined a re-election to the office he has so acceptably filled for the past four years, it is therefore

Resolved, That, in parting with Dr. Rogers, we desire to place on record our high appreciation of the courteous and impartial manner with which he has presided over our deliberations, as well as our appreciation of the valuable time and talents he has devoted to the service of this Institute, and we indulge the hope that in the future, as in the past, it may have the benefit of his extensive research and great experience.

The Library.

The Committtee on the Library respectfully report:

That during the year 1878, just passed, the gradual improvement of the Library has been continued.

We have added to our collection 806 volumes and 43 maps. Of the books, 455 are bound and 351 unbound.

Total number of bound volumes Dec. 31, 1877,	13,104
" " " " Dec. 31, 1878,	13,559
	455

During the past year we have arranged an exchange with the Royal Academy of Belgium, by which we are to receive a complete set of their Proceedings from the beginning, in return for a full copy of the JOURNAL of the Institute, with continued exchange.

Also, by the liberality of the French Government, we acquire all the volumes necessary to complete our collection of French Patents; also the *Annales des Ponts et Chaussés*, with many valuable Reports and the *Annales des Mines*, for which we are to send a full copy of the JOURNAL in exchange.

A continued and successful effort has been maintained to fill up the sets of some valuable serials. Although the result does not swell the Catalogue, it increases the value of the Library for reference.

The use of the Library by the members continues to increase with its improvement. During the past year 1,984 volumes have been taken out by 265 members, while the use of the books in the Hall, both by reading and by making extracts, has been continued.

The Institute is aware that the Library is to receive the benefit of the liberal gift of $10,000 from Mrs. Bloomfield H. Moore, who thus desires to establish a memorial of her late husband.

No more fitting tribute to the memory of an honored member could have been designed, and the committee feel a peculiar satisfaction in accomplishing an object with which they sympathize so much.

Signed, by order of the Committee,

W. P. TATHAM, *Chairman.*

PHILADELPHIA, *Jan.* 6, 1879.

The representative of the Institute in the Pennsylvania Museum and School of Industrial Art presented the following report:

The progress made during the past year in the development of the original plan of the institution has greatly increased its usefulness.

The arrangement with the Permanent Exhibition Company was entered into on May 10th, 1877, by which that corporation was to receive all the entrance money and issue tickets admitting to both its building and Memorial Hall, and pay to the Museum corporation a fixed sum. The Exhibition Company having failed to pay over the money due under their contract, the Museum was deprived of a considerable portion of its income, and in April last the agreement was cancelled and the receipts at Memorial Hall passed directly into the treasury of the Museum. Since that time the admissions have considerably fallen off, owing, no doubt, in a large degree to the difficulty of access to Memorial Hall from the street car lines on Elm avenue.

The experiment of opening the collections to the public on Sundays has proved satisfactory, both in the character of the visitors and in their number; more than 20 per cent. of the total admissions since April 6th having been on Sundays.

During the year the collections of English pottery and porcelain lent by Messrs. Daniell & Sons, of London; of specimens of enameled glass, of Brocart, and of pottery, by Deak, lent by Messrs. Landos & Co., of London, and of the collection of Spanish pottery and glass, lent by Signor Reano, of Madrid, were returned to their owners.

To fill the temporary void thus caused, the Trustees invited from citizens, the loan of suitable objects for exhibition, to which they received a hearty response. The period of the loan terminated on Nov. 16th, but many of the depositors have allowed their objects to remain for an indefinite time.

The collection illustrative of the native productions and the manufactures of British India, loaned after the close of the Centennial Exhibition, has, through the kind offices of Sir Herbert B. Sanford, been presented to the Museum.

Other gifts have been received from private citizens, prominent among which is a cork model of the Temple of Neptune, at Pastum, sent from Naples by Mr. Fred'k Graff.

The Numismatic and Antiquarian Society of Philadelphia has deposited its valuable and extensive collection of coins, together with similar collections belonging to the American Philosophical Society, and the Library Company of Philadelphia.

During his visit to the Paris Exposition, the Secretary purchased a few specimens of art workmanship and a considerable number of books, on Industrial Art, for the Library.

The collection illustrative of mining and metallurgy, belonging to the American Institute of Mining Engineers, still remains on loan, and, from negotiations now pending, it is expected that the collection will soon be permanently deposited with the Museum.

During the last session of the Legislature an effort was made to obtain State aid in the work of the corporation, but it resulted only in an appropriation of $5,000 for the maintenance and repair of Memorial Hall, a sum considerably less than that actually expended for that purpose.

The provisions of the U. S. Tariff were found insufficient to admit free of duty many objects imported by educational institutions, and during the last session of Congress an amendment was made to the law, by which nearly all articles the Museum may wish to import will be admitted free, and which relieved a number of purchases made at the Centennial which up to that time were under bond.

The progress of the schools during the year has more than equalled the expectation of the Trustees. The instruction has been in the direction of self-help, and to instil into the minds of students the principles involved, rather than allowing them to learn by rote. The hours of attendance were changed at the commencement of the autumn term, requiring each class to be present only twice each week, instead of each day, as before, thus enabling the same instructors to teach twice as many pupils. The number now attending regular classes is 200.

The art needle-work class has been continued with marked success as to the instruction given and the character of the work produced, although it has not been self-supporting. The number of free pupils is kept constantly at 25, and after they have acquired sufficient proficiency they are employed on orders at pay. In the management of these classes the Trustees have been greatly aided by the Advisory Committee of twelve ladies, who devote much time to the work.

So far the work of the different departments has been carried out as fully as means would permit, and the Trustees confidently appeal to the people of all classes for that financial aid necessary to complete what has been so well begun.

J. B. KNIGHT.

Profs. Houston and Thomson exhibited, in operation, two forms of their vibrating electric lamp, operated by currents produced by a dynamo-electric machine, also of their own design and construction.*

They also gave an illustration of the possibility of transmitting power for long distances, through small wires, by means of electrical currents. The currents of high electrio motive force generated by one machine were conveyed through two fine wires, of combined area of ·004 of an inch, to another machine, which in turn gave off considerable power.†

The tellers of the election held this day presented their report, and, in accordance therewith, the President declared the following members elected as officers and managers:

President, William P. Tatham.
Vice-President, Jas. E. Mitchell.
Secretary, J. B. Knight.
Treasurer, Fred'k Fraley.
Managers to serve three years, Hector Orr, R. E. Rogers, Elihu Thomson, Cyrus Chambers, Jr., Wm. V. McKean, Wm. Sellers, H. R. Heyl, J. Vaughan Merrick.

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* This machine will shortly be described in the JOURNAL.

† For demonstration of the principles involved, see page 36 ante.

Manager to serve two years, to fill vacancy, C. S. Heller.

Representative in the Board of Trustees of the Pennsylvania Museum and School of Industrial Art, J. B. Knight.

Dr. Rogers, the retiring President, then conducted his successor, Mr. Tatham, to the chair, and expressed his gratification in resigning it to one so earnest in promoting the work and interests of the Institute and skilful in administration.

Upon assuming the chair Mr. Tatham thanked the members for the honor so unanimously conferred upon him, and asked their indulgence for any deficiency that might arise from his want of experience as a presiding officer. He invoked their co-operation and assistance in promoting the usefulness and prosperity of the Institute; for prosperity and usefulness go hand in hand. He called attention to the facts that in 1824, when the Institute was founded, the city contained about one-sixth of its present population, and that within the first year thereafter there were over 600 members enrolled;* that of the largely increased number of inhabitants of Philadelphia we should now have as large a proportion of members as in the earlier years, and this he believed could be easily accomplished, if every member would call the attention of his friends to the advantages the Institute offers in its meetings, library, lectures, sections and committees, to all persons interested in the progress of science and the mechanic arts, whether as teachers or learners, or as desiring the benefit and instruction of others.

The Secretary's report embraced J. d'Auria's Steam Engine Governor;† and Meeker's Automatic Coin Cashier, to facilitate making change, consisting of a series of receptacles for coin of the various denominations, standing at an inclination from the perpendicular, and having at their lower ends a slide, which, when moved to the proper position, allows one piece of coin to drop out. The slides are marked with the denominations of the various coins contained in the receptacles, and are operated by passing the thumb upon an extension thereof projecting to a convenient distance, and the palm of the hand is at the same time held under to receive the coin as it drops out: Crawford's Automatic Cut-off for Water Pipes, consisting of a differential expansive thermometer, so connected to a cock at the lower end of the service pipe in the house, that when the temperature falls to the freezing point a catch is disengaged, allowing a weight attached to the lever of the cock to fall and close it, at the same time opening a drip, allowing the water contained in the pipe to escape: The Hartford Slat Window Blind, in which the slats are operated by means of a rack concealed in the frame and engaging into pinions attached to the trunion of each slat, thus doing away with the end usually attached to the edges of the slats, and allowing the latter to close more tightly: Clark's System of Ventilating House Drains: Cudell's Sewer Gas Trap, and P. E. Jay's System of aging Liquors.

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* There were 637 members enrolled in 1824.

† A description of this governor will appear in the next number of the JOURNAL.

Dr. Isaac Norris exhibited and explained an improvement to the spectroscope devised by him, in which the table of the instrument, supporting prisms, telescope, etc., instead of being fixed firmly to the pillar and base, have a hinged motion, similar to that of the best forms of microscope, enabling the student to use the spectroscope on an ordinary table, while the telescope being inclined gives the best position for making accurate observations, and with the greatest comfort to the observer.

The violet end of the spectrum is raised with the elevation of the telescope, but the lines are readily made vertical by a slight turning of the slit, and in practice it is not found at all objectionable, the reading from the vernier of the distance apart of the lines being the same as when the table is in a horizontal position. A key which is furnished permits one to clamp it firmly in any position. Another advantage of the arrangement may be stated to be the facility with which any portion of the flame from a Bunsen burner can be observed without altering the height of the lamp, a slight elevation or depression of the telescope effecting it, and the same applies to the tubes used for obtaining the spectra of liquids and gases.

It can be adapted to any spectroscope, and of course pemits of its use in the ordinary way, the wonder being that it was not thought of before, so many advantages coming from it.

Under the head of deferred business, the resolutions from the Board of Managers and from the Committee on Science and the Arts relative to the awards of medals were taken up, when, on motion of Mr. Weaver, the further consideration of the subject was postponed to the next meeting.

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On motion, the meeting adjourned.

J. B. Knight, *Secretary.*

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

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THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the JOURNAL.

CONCERNING $\frac{T_1-T_0}{T_1}$; OR, THE LIMIT OF EFFICIENCY OF HEAT ENGINES.

By J. F. KLEIN, D. E.,

Instructor in Dynamical Engineering, Sheffield Scientific School.

A thermodynamic heresy of latter days having denied that this classic fraction represents the maximum efficiency of all heat engines irrespective of the nature of the working substance employed, and, having spread itself unopposed far and wide over the land to the injury and confusion of those not well grounded in the first principles of thermodynamics, it has been thought not inopportune to examine the grounds on which the aforesaid heresy seeks to justify itself and to restate, as simply as possible, the reasons for the faith in the applicability of this *coefficient of work* to all possible heat engines.

From a paper first read to the American Association for the Advancement of Science, and afterwards published, in its "Proceedings," in the JOURNAL OF THE FRANKLIN INSTITUTE, and also in part and substance in the *Int. Sci. Series* and *Pop. Sci. Monthly*,* we glean the following:

(1) The present type of vapor engines, represented by the steam engine, has an efficiency, theoretically attainable, which is *greater* than $\frac{T_1 - T_0}{T_1}$.

(2) Gas engines have been frequently designed and built whose theoretical efficiency was *unity*.

(3) It is theoretically possible to have a "new type of steam engine" which will produce work without rejecting any heat.

These three forms of grievous error characterize the heresy and shall be destroyed, root and branch ,in the latter parts of this paper, the earlier parts being devoted to demonstrating anew the principles underlying the efficiency of all heat engines. These principles, expressed in the form of propositions, are as follows:

Proposition A.—It is impossible for any heat engine to perform work by the expansion and contraction of the volume of its working substance without rejecting heat.

Proposition B.—The efficiency of a reversible engine, which receives and discharges heat only at its upper and lower limits of temperature respectively, is *not less* than that of any other engine having the same range of temperature.

Corollary 1.—A reversible engine which receives and discharges heat only at its upper and lower limits of temperature respectively is an engine of maximum efficiency for its range of temperature.

Corollary 2.—A reversible engine which not only receives and discharges heat at its upper and lower limits of temperature respectively, but also receives and discharges heat at intermediate temperatures in such a way that the amounts received and rejected at any given temperature are always equal, is an engine of maximum efficiency for its range of temperature.

Corollary 3.—Tne maximum efficiency of one kind of reversible heat engine is equal to that of any other having the same range of temperature; or

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*See Proc. Am. Ass. for the Adv. of Science, 1877, JOURNAL FRANK. INST., Vol. CIV., pages 252, 325, 389—Growth of the Steam Engine. *Int. Sci. Series*, 1878.—Growth of the Steam Engine, *Pop. Sci. Monthly*, 1878. All by Prof. R. H. Thurston. See also "Theoretical Steam Engine," by Chas. E. Emery, *Sci. Am. Supp.*, July 18, 1877.

The maximum efficiency of an engine is independent of the nature of the working substance employed, and is simply a function of the two limits of temperature between which the engine works.

Proposition C.—Other things being equal, a reversible engine is more efficient than an irreversible one.

Proposition D.—The maximum efficiency of any heat engine is represented by the proper fraction $\frac{T_1 - T_0}{T_1}$, T_1 and T_0 being respectively the highest and lowest absolute temperatures attainable by the working fluid in the engine.

At this point we may be allowed to call attention to the incomplete treatment given to this matter of efficiency in the elementary treatises on heat. Corollary 3 is generally mentioned, sometimes proved for a particular case. Propositions A and B are either tacitly assumed as self-evident, or only Proposition B demonstrated for the common case when there are but two reservoirs of heat (boiler and condenser). The efficiency of engines having "regenerators"* is generally ignored, the reason probably being that the use of more than two reservoirs renders the demonstration somewhat more complicated. Proposition C is often assumed to be identical with a particular case of proposition B: we ourselves have not been able to demonstrate it rigidly without recourse to the calculus. Proposition D is easily obtained from the preceding propositions and the sample formulæ of proposition C. In the more advanced treatises on heat—those by Rankine, Hirn, Zeuner and McCulloch—all the above principles follow readily from equations established by the aid of the calculus. To those not familiar with this branch of mathematics, such deductions are not perfectly satisfactory, and to this class of readers it is hoped most of the demonstrations given will not be without value.

Before demonstrating the above propositions, we will first define what is meant by a *cycle* in thermodynamics and then not only describe the cycles belonging to the two theoretically perfect engines, but also describe the cycle belonging to the more general and imperfect case. Definitions of reversibility and efficiency of engines will also be given, and the general method of demonstration indicated.

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* This term is applied in air engines to a mass of metal plates or network of wires which serve to absorb the heat of the charge of air as it is leaving the working cylinder of the engine and give it up again to the new charge of air while on its way to receive a new supply of heat from the furnace.

The simple and fruitful conception of a *cycle* we owe to Carnot. It consists in supposing a body which has experienced a certain number of transformations to be brought back to identically the physical state as to density, temperature and molecular constitution which it possessed at the beginning of the series of changes. The initial and final states of the body being the same, its *internal energy* at the beginning and end of the cycle will be the same, and any mechanical effects that may have been produced during the complete cycle of operation can only be ascribed to purely external thermal changes. A cycle can be represented graphically by a series of lines forming a closed curve, as *a, b, d, c, a*, (Fig. 1). When the coördinates of the diagram are volumes and pressures, a cycle may also be called an indicator diagram, because it represents not only the changes of pressure and volume experienced by the body, but also the work done by the latter.

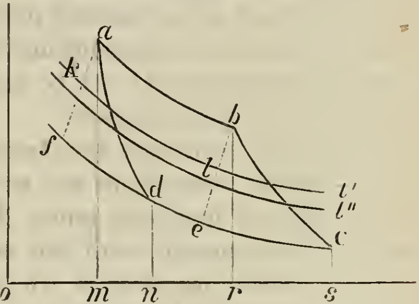
The simplest of the two perfect engines is that which describes an indicator diagram called "Carnot's cycle," which consists of "four operations" represented by the four curves, *ab, bc, cd, da* (Fig. 1). We will describe the four operations: Suppose a body in the cylinder of an engine to have a volume *om* and pressure *ma*, and that the temperature corresponding to this volume and pressure is t_1; if the body is now placed in communication with a source of heat, *M*, at the same (or insensibly higher) temperature t_1, and be allowed to expand so that its temperature remains constantly equal to that of the source *M*, it will perform the external work *mabr*, and will receive an amount of heat from *M* represented by Q_1. This ends the first operation, which is sometimes briefly described by saying the body receives heat along an isothermal *ab*. During the second operation the source of heat *M* is supposed to be removed and the body to expand without transmission of heat in the non-conducting cylinder till its temperature has fallen to that of the refrigerator *N*, namely, t_0; the body will then have again done work represented by *rbcs*, but without any transmission of heat to or from external bodies. This operation is also described thus: The body expands along the adiabatic curve *bc*. In the third operation the body is supposed to be in contact with the refrigerator *N*, and is then compressed by means of a piston so that its temperature remains constantly equal to that of *N*. The work expended on the body will then be equal to *cdns*, and the heat withdrawn from the body may be represented by Q_0, which is always less than Q_1. The compression is continued till the body reaches a state *d*, from which, by means of the fourth operation, consisting of compression without thermal communication with external bodies, the body may be brought back to its original, primitive state *a*. The work expended in the body along the adiabatic *da* will be *damn*, and the last two operations are often briefly described as compression along the isothermal *cd* and adiabatic *da*. During this cycle of operations a quantity of heat $Q_1 - Q_0$ has been transformed into the work $W = J(Q_1 - Q_0)$=area *abcd*, and contemporaneously a quantity of heat Q_0 has been transferred from the hot body M to the cold body N. This is a point that has not received in elementary treatises on heat the attention that it deserved; this quantity of transmitted heat Q_0 stands in just as definnite and persistent a relation to the work performed as the transformed heat $Q_1 - Q_0$. It cannot be too strongly insisted upon that whenever, in a cyclical process, mechanical effect is produced we always have not only a *disappearance* of heat equal to the work performed, but a *transmission* of heat from a hot body to a cold body. This being true, the working fluids which actuate our heat engines, must also serve as mediums for the transmission of heat, and must, therefore, not only *receive* heat, but *reject* heat. Carnot, endeavoring to explain *how* work was obtained from heat, called attention to the fact that the performance of work in steam and air engines was always accompanied by a transmission of heat. His assumption of the Caloric theory, however, led him into the error of supposing that all heat received would be rejected; that, as much heat would be found in the condenser as had been received by the boiler, and, therefore, that the performance of work was due to the *mere transmission* of heat. We now know that this was only an approximation to the truth, that of the heat received by the working substance a part is transformed into work and the remainder transmitted to a colder body.

Before demonstrating the correctness of this assertion, we will call attention to another of Carnot's fruitful conceptions: The reversible cycle, which consists in supposing the working substance employed in the theoretical engine to pass through such a series of transformations that the physical, chemical and mechanical changes that may accompany or cause them can take place in the opposite sense when the engine is reversed; then, if while the engine is running forward, the result of the cycle of operations *abcda* is the production of an amount of work W, the disappearance of a quantity of heat $Q_1 - Q_0$, and the transmission of the heat Q_0 from the source M to the refrigerator N, the result of the reversed cycle *adcba* will be the *expenditure* of an equal amount of work W, the *generation* of an equal quantity of heat $Q_1 - Q_0$ and the transmission of the heat Q_0 from the cold body N to the hot body M. For, when the cycle is reversed, the working substance receives back from its former refrigerator N an amount of heat Q_0 equal to that discharged into N during the first or forward set of operations and gives up to the source M a quantity of heat Q_1 equal to that previously received. This conception of reversibility is a purely ideal one and can never be realized completely by an actual engine, for it requires that the temperature of the working substance should not be sensibly different from those of the external bodies with which it is brought into thermal communication, and that its expansive force should not be sensibly different from the external pressure to which it is opposed.

Carnot's cycle, which we have been hitherto considering, is of great interest because it represents the simplest perfect engine; in it only two reservoirs of heat—the source M and the refrigerator N—are in thermal communication with the working substance, and keep the latter at constant temperature while transfer of heat is taking place, the necessary fall and rise of temperature being respectively accomplished by the expansion and contraction of the volume without any *thermal* communication with external bodies. In graphical thermodynamics this is briefly expressed by saying that Carnot's cycle is composed of two isothermal and two adiabatic curves.

There are, however, an infinite number of cycles or diagrams composed of only four curves, which also represent theoretically perfect engines. Two, *ab* and *ef* (Fig. 1), of these four curves, as in "Carnot's cycle," are isothermals; the other two, *be* and *af*, are called by Rankine *isodiabatics*, and represent the changes of volume and pressure of the working fluid when respectively discharging and receiving heat at temperatures lying between the extremes. They are always found in pairs, being inseparably connected by the condition that the heat discharged by the fluid at one temperature must be exactly equal to that received by it when at the same temperature, or, referring to the diagram, this condition may be expressed by saying that the heat discharged along the element l, lying between the isothermals t' and t'', must be exactly equal to that received along k. But, in order that this condition may be fulfilled and the series of changes represented by *be* and *af* be reversible, more than two reservoirs of heat are needed—an indefinite number, in fact—one for each temperature. One reservoir may then be made to do duty both as a source and as a refrigerator, receiving as much as it imparts and having at the end of the operation as much heat as at the beginning. In such a cycle the heat expended and rejected will (as in Carnot's cycle) be that which is furnished and abstracted by the reservoirs M and N along the isothermals *ab* and *cf*. We will hereafter prove that the efficiency of an engine having the indicator diagram *abef* is equal to that describing Carnot's cycle, or diagram *abcd*.*

Fig. 1.



The two cycles hitherto described have been chosen because of their simplicity and because they represent the only two classes of engines whose efficiency is equal to the maximum.

As may be easily imagined, there are an infinite number of others whose working fluids receive and discharge heat at temperatures lying between the available extremes, without necessarily receiving and discharging equal amounts, and which have numerous reservoirs not necessarily at the same temperature as the working substance during the transfer of heat. The indicator diagram, *abcda* (Fig. 2), may be taken as the representative of such an engine. In this case, as in every other, the efficiency is measured by the ratio

$$\frac{W}{JQ_1} = \frac{\text{Work done}}{\text{Heat expended (ft. lbs.)}} \tag{1}$$

In the simple cycle, *abcda* (Fig. 1), the heat expended is identical with the total heat received by the working substance, and the heat permanently rejected with the total amount abstracted; but in *abefa* (Fig. 1) we no longer find this to be the case, the heat expended and rejected being respectively equal to the heat lost by the reservoir at the highest temperature and that gained by the reservoir at the lowest temperature, the losses of all the intermediate ones being balanced by their gains. In the general case represented by *abeda* (Fig. 2) we must in like manner be careful to distinguish between the heat expended and the total heat received by the working substance, also between the total amount of heat abstracted and that part of it which is rejected, never to be again used in subsequent cycles. Since we are here seeking to determine the conditions of maximum efficiency, we will suppose our engines to run without friction, that there are no leakages of heat due to imperfect protection against induction and radiation, and that no losses occur which are due to permanently rejecting heat capable of partially or completely compensating the intermediate reservoirs for their losses of heat. Assuming that all these sources of loss have been removed, we can now define the quantity of heat expended in a cyclical process to be that quantity which is equivalent to the work done plus the heat permanently rejected; expressed analytically, this is

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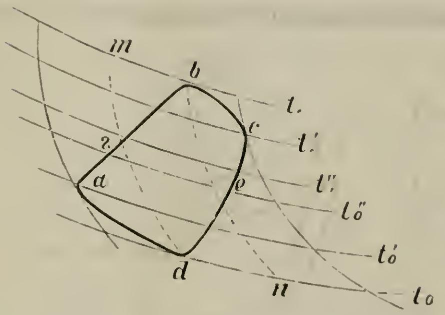
* One of the isodiabatic curves may be arbitrarily assumed and the other obtained by combining the above condition with the equation expressing the relation betweeen the volume, pressure and temperature of the working fluid employed. The adiabatics are only a particular case of the iso-diabatics; that, namely, in which the transmission of heat equals zero, and since the former are often and properly called *curves of no transmission of heat*, the latter may, in the above limited sense, be called *curves of equal transmission of heat*.

Fig. 2.



$$J\,Q_1 = W + J\,Q_0 \tag{2}$$

which can also be written

$$W = J\,(Q_1 - Q_0) \tag{3}$$

where J represents the mechanical equivalent of heat, and Eq. (3) the law of the equivalence of heat and work when applied to cyclical processes. This will perhaps be more evident if we introduce into Eq. (3) the terms which have disappeared because of theabove-mentioned compensation; then

$$W = J\,[Q_1 + q - (q + Q_0)] \tag{4}$$

when $Q_1 + q$ represent the total amount of heat received, and $q + Q_0$ the total amount rejected by the working substance.

In demonstrating the propositions given at the beginning of this article we shall only make use of two principles, which, though simple, are the foundation of the whole Science of Heat. They are

I. "When work is transformed into heat, or heat into work, the quantity of work is mechanically equivalent to the quantity of heat."

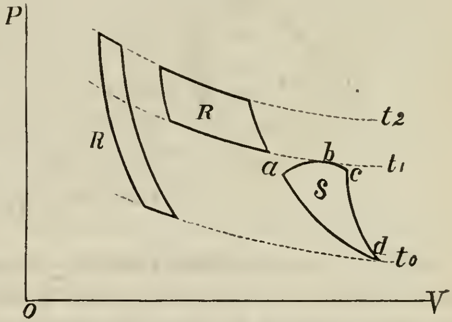
II. "It is impossible for a self-acting machine, unaided by any external agency, to convey heat from one body to another at a higher temperature."*

These two principles are sometimes called the first and second laws of thermodynamics; in the form here given they are simply "the condensed expression of experimental facts."

Proposition A.—*It is impossible for any heat engine to perform work by the expansion and contraction of the volume of its working substance without rejecting heat.*

Let S (Fig. 3) represent the indicator diagram† of an engine which rejects no heat and yet performs work, its range of temperature being t_1, t_0. In like manner, let R be the diagram of a reversible engine which receives all its heat at the temperature $t_2 > t_1$ and rejects heat at any temperatures equal to or less than t_1. Let K be the source from which R draws its heat, N the reservoir or refrigerator into which it discharges heat, and M the source or sources of heat for S, with temperature equal or less than t_1. When both R and S are performing work, let the work produced by R be equal to that produced by S; then

Fig. 3.



W_1 = work performed by engine R

W_1^1 = " " S

Q_1 = heat furnished to engine R by K

Q_1^1 = " " S " M

Q_0 = heat abstracted from engine R by N

When engine R is reversed we have

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* This principle was first enunciated by Clausius in this slightly different form, "Heat cannot, of itself, pass from a colder to a warmer body."

† The diagrams used in all the demonstrations are for the purposes of illustration and abbreviation, not for graphical demonstration.

W_1 = work expended on engine R
Q_0 = heat furnished to " " by N
Q_1 = " abstracted from " " " K

In either case the values of Q_1, Q_0 and W_1 are the same, and we have from our first principle:

$$W_1 = J\,(Q_1 - Q_0)$$

and if S can perform work without rejecting heat

$$W_1^1 = J\,Q_1^1$$

and since $$W_1 = W_1^1 = J\,(Q_1 - Q_0) = J\,Q_1^1$$

we have $$Q_1 = Q_0 + Q_1^1$$

Now suppose the two engines to be so combined that S will drive R backward, the latter will then transform the work expended on it into the heat Q_1^1, and will also abstract the heat Q_0 from the refrigerator N and transmit both quantities of heat Q_1 to the reservoir K at the temperature $t_2 > t_1 > t_0$. Since the work expended in running one engine is exactly balanced by the work developed in the other, we have here a self-acting machine, which, unaided by any external agency, transmits heat from two colder reservoirs, M and N, to a hotter reservoir, K, which is contrary to our second principle; therefore the hypothesis that any heat engine can perform work in a cyclical process without rejecting heat is false, which was to be proved.

REMARK.—It should be noticed that the result of the combination involves no contradiction of the first principle; for the heat Q_1 gained by the reservoir K is exactly equal to the heat $Q_0 + Q_1^1$ lost by the reservoirs N and M.

Proposition B.—*The efficiency of a reversible engine which receives and rejects heat only at its upper and lower limits of temperature, respectively, is* NOT LESS *than that of any other engine having the same range of temperature.*

Let the reversible engine, which receives and discharges heat at the highest and lowest temperatures, t_1, t_0, respectively, be represented by R, and have for its indicator diagram *mbnd* (Fig. 2), and let any other engine having the same range of temperature be represented by S, and have an indicator diagram of any form, as *abcda* (Fig. 2), but included between the isothermals t_1 an t_0.

Suppose that besides the two reservoirs of heat (M and N), at the highest lowest temperatures (t_1, t_0, respectively) there are an indefinite number of intermediate reservoirs (M_1^1, M_1'' . . . . N_0^1) which while transferring heat may or may not be at the same temperature as the working substance, according as the cycle *abcda* is reversible or irreversible. Now suppose both engines to perform work, and that

w = work performed by engine R
W = “ “ S
q_1 = heat received by R from M
q_0 = “ abstracted from R by N
$Q_1 + Q$ = total heat received by S from $M, M_1^1 \ldots N_0^1$
$Q_0 + Q$ = “ abstracted from S by $N, N_0 \ldots M_1^1$
Q_1 = heat expended in driving S
Q_0 = “ permanently rejected by S
Q = “ not “ “ “
= “ returned to $M_1^1 \ldots N_0^1$

When the engine R is reversed it no longer performs but consumes work, transforming that expended in driving it into heat, which it delivers to M; it also abstracts heat from the coldest reservoir, N, and delivers it to the hottest reservoir, M; in this case (R reversed)

w = work expended in driving R
q_0 = heat received by R from N
q_1 = “ abstracted from R by M

In either case the values of w, q_1 and q_0 are the same, and we have from our first principle

$$w = J(q_1 - q_0) \text{ and } W = J[Q_1 + Q - (Q + Q_0)] = J(Q_1 - Q_0)$$

Now if it be denied that the efficiency of R is *not less* than that of S, we must have

$$\frac{w}{Jq_1} < \frac{W}{JQ_1}$$

This, we will show, leads to a contradiction of our second principle; for suppose the work that can be performed by the reversible engine R to be exactly equal to that performed by S, then if the two engines are coupled together so that S drives R backward, the whole work performed by S will be expended in driving R and will be transformed in the working substance of the latter into heat, which is finally delivered to the hottest reservoir, M. Besides transforming work into heat, the engine R abstracts heat equal to q_0 from the coldest reservoir, N, and transfers it to the hottest reservoir, M. The total amount of heat delivered by R to M will then be

$$q_1 = \frac{W}{J} + q_0 = Q_1 - Q_0 + q_0$$

There is a part (Q_0) of the total heat abstracted ($Q_0 + Q$) from the working substance of S, which must be regarded as permanently rejected by the engine because it cannot assist in diminishing the expenditure of heat in subsequent cycles equal and similar to *abcda*. Now suppose that after the engine S has completed its cycle, the permanently rejected heat (Q_0) be allowed to flow, by *conduction or radiation* into the coldest reservoir, N, and that the remaining part, Q, of the total heat abstracted be also allowed to flow by *conduction or radiation* into these reservoirs (M_1^1 M_1'' . . . . N^1_0) of intermediate temperature, which have lost heat by supplying it to the working fluid of the engine S. If this compensating process be so conducted that the restoration of heat takes place between reservoirs as nearly as possible of the same temperature, the heat restored (Q) will be a maximum for the given cycle *abcda*, and the heat permanently rejected (Q_0) a minimum. The final result of this procedure is that at the end of the cycle *abcda* every reservoir in thermal communication with the working substance of the engine S, except the coldest one (N), will either be in the same condition that it was originally, or will have lost heat. Only the coldest reservoir (N) will have gained heat, and this only to the extent (Q_0) — the minimum amount of permanently rejected heat.

It will be remembered that in consequence of the denial of our present proposition we obtained

$$\frac{w}{Jq_1} < \frac{W}{JQ_1}$$

If we combine this inequality with the equation

$$w = W = J(q_1 - q_0) = J(Q_1 - Q_0)$$

we get

$$Q_1 < q_1 \text{ and } Q_0 < q_0$$

That is, the heat gained (Q_0) by the coldest reservoir (N) is less than the heat (q_0) which it loses, the difference ($Q_0 - q_0$) having been transferred to the hottest reservoir (M). The losses suffered by the various reservoirs of S will then be

$$Q_1 - Q_0 + q_0$$

and the gain experienced by M,

$$q_1$$

The preceding equation shows us that these two expressions are exactly equal; there has, therefore, been no destruction or creation of heat energy, which is in accordance with our first principle. But in our combination of engines the work expended is exactly equal to that produced, and we have here, therefore, a self-acting machine which, unaided by external agency, is capable of transferring heat from the colder bodies M_1', M_1'', ... N to the hotter body M, which is contrary to our second principle, "Heat cannot, of itself, pass from a colder to a warmer body." Therefore the supposition that

$$\frac{w}{Jq_1} < \frac{W}{JQ_1}$$

is false, which was to be proved.

REMARK.—It should be noticed that the foregoing demonstration is applicable whether S be a reversible or irreversible engine, for only R is reversed.

Corollary.—*A reversible engine which receives and discharges heat only at its upper and lower limits of temperature, respectively, is an engine of maximum efficiency for its range of temperature.*

This corollary is an immediate consequence of the proposition just demonstrated, for since the efficiency of R is not less than the most efficient of all the possible engines represented by S, it must be equal or greater, and R is therefore an engine of maximum efficiency for the given range of temperature.

Corollary 2.—*A reversible engine which not only receives and discharges heat at its upper and lower limits of temperature, respectively, but also receives and discharges heat at intermediate temperatures in such a way that the amounts received and rejected at any given temperature are always equal, is an engine of maximum efficiency for its range of temperature.*

It will only be necessary to prove that the efficiency of the reversible engine contemplated by the present corollary, and which we will call S^1, is equal to that of R, which has just been shown to be an engine of maximum efficiency for its range of temperature.

Since S^1 is only a particular case of the general engine S of proposition B, it follows from that proposition that the efficiency of S^1 cannot be greater than that of R, and we have now only to prove that S^1 cannot be less than R.

Suppose S^1 is less than R, then we must have:

$$\frac{W_1^1}{J\,Q_1^1} < \frac{w}{Jq_1}$$

Now let R be so chosen that it will perform the same amount of work as S^1, and then couple the two together so that the one supposed to be most efficient will drive the other backward, *i. e.*, R drives; then, by reasoning exactly like that of proposition B, we can show that the quantity of heat in the intermediate reservoirs of S^1 will be the same at the end of the cycle as at the beginning, and that the only change that has taken place is the transfer of heat from the coldest reservoir N to the hottest M by a self-acting machine unaided by external agency, which is contrary to the second principle and consequently the supposition that the efficiency of S^1 can be less than that of R is false, and since it is not greater, we must conclude that the efficiency of S^1 is equal to that of R, in other words, S^1 is an engine of maximum efficiency for its range of temperature, which was to be proved.

Corollary 3.—*The maximum efficiency of one kind of reversible heat engine is equal to that of any other having the same range of temperature; or,*

The maximum efficiency of an engine is independent of the nature of the working substance employed, and is simply a function of the two limits of temperature between which the engine works.

The previous propositions and corollaries apply equally well to all heat engines whatever, for they contain no limiting conditions which would restrict them to any particular working substance. It has been thought desirable, however, to emphasize this point in the present corollary. Here, therefore, different kinds of heat engines must be understood as meaning engines differing only in the working substances driving them, moreover the maximum efficiency of one kind of heat engine must, in accordance with corollary 1, be understood to mean the efficiency of that kind of engine when receiving and discharging heat only at its upper and lower limits of temperature; thus understood, the two forms of this corollary become equivalent, and one demonstration will answer for both. If either be denied, it will follow that the maximum efficiency is not constant, being greater for certain kinds of heat engines than for others; it will then be easy to show by methods precisely analogous to those already employed that a result will be arrived at contrary to the oft-quoted second principle.

Proposition C.—*Other things being equal, a reversible engine is more efficient than an irreversible one.*

It will be remembered that an engine was defined as irreversible when the temperature of its working substance differed sensibly from that of the external bodies with which it was brought into thermal communication, or when the expansive force differed sensibly from the external and opposing force.

When the first of these conditions of irreversibility only is present, it is easy to show by the foregoing methods that, other things being equal, a reversible engine is always more efficient than an irreversible one; but when the latter condition is present these methods are no longer applicable, for there is then either friction among the particles of the working substance or sensible motion, either of which will produce heat, but the influence of which on the efficiency it is not easy to ascertain without recourse to analytical methods. Before employing these, however, we will say that generally in an irreversible engine the external opposing force is less during expansion and greater during compression than the expansive force of the working substance; the external work performed in an irreversible engine, for a given quantity of heat expended, will therefore be less than if these opposing forces were equal as in the reversible engine.

The formulæ which are to aid us in demonstrating the present and following propositions, are those which are now well established as the analytical expressions of the two fundamental laws of the mechanical theory of heat when applied to cyclical processes. They are:

$$\text{I.}\quad W = J\,\Sigma\,Q \qquad\qquad \text{II.}\quad \int \frac{dQ}{T} \leqq 0$$

Where

W = work done during a cycle

$+Q$ = heat received by working fluid

$-Q$ = heat abstracted from working fluid

$+dQ$ = increment of heat at absolute temperature T

$-dQ$ = decrement of heat at absolute temperature T

In expression II. the sign of inequality belongs to irreversible cycles, and that of equality to reversible ones; the integral sign extends over all those portions of the cyclical process at which heat is received or abstracted by the working fluid. Then, if as before we let

Q_1 = heat permanently expended.

q = heat received and restored.

Q_0 = heat permanently discharged.

T_1, T_0 = absolute temperatures corresponding to Q_1 and Q_0

τ_1, τ_0 = absolute temperatures of q when respectively received and restored.

Expressions I. and II. will then become:

$$W = J\,(Q_1 + q - q - Q_0) = J\,(Q_1 - Q_0) \quad \text{I.}^1$$

$$\int \frac{d\,Q_1}{T_1} + \int \frac{d\,q}{\tau_1} - \int \frac{d\,q}{\tau_0} - \int \frac{d\,Q_0}{T_0} \overset{<}{=} 0 \quad \text{II.}^1$$

Equation I.[1] shows us that for a given quantity Q_1 of heat expended W will be a maximum when Q_0 is a minimum. From formula II.[1] we can determine one of the conditions which will make Q_0 a minimum, for, transposing, we have

$$\int \frac{d\,Q_0}{T_0} \overset{>}{=} \int \frac{d\,Q_1}{T_1} + \int \frac{d\,q}{\tau_1} - \int \frac{d\,q}{\tau_0} \qquad \text{II}^1.$$

This equation shows us that other things being equal, Q_0 will be least (and consequently the efficiency greatest) when the sign of equality is employed, *i. e.*, when the process is a reversible one, which was to be proved.

Proposition D.—*The maximum efficiency of any heat engine is represented by the proper fraction*

$$\frac{T_1 - T_0}{T_1}$$

T_1 and T_0 being respectively the highest and lowest absolute temperatures attainable by the working fluid in the engine.

It was established in corollary 1 that when $q = 0$ and Q_1, Q_0 are respectively received and discharged at the highest and lowest attainable temperatures, the efficiency of the engine would be a maximum. From corollary 2 we have that when $\tau_1 = \tau_0$ and Q_1, Q_0, are respectively received and discharged at the highest and lowest attainable temperatures, the efficiency of the engine is also a maximum. Introducing either of these sets of conditions of maximum efficiency into *Equation* II. we get

$$\frac{Q_0}{T_0} = \frac{Q_1}{T_1} \qquad \text{II.}^{11}$$

substituting for Q_0 in Equation I. its value obtained from Equation II.[11], and reducing we get

$$\frac{W}{J\,Q_1} = \frac{T_1 - T_0}{T_1} \qquad \text{III.}$$

Where $\frac{W}{J\,Q_1}$ equals the maximum efficiency of any kind of heat engine, and T_1, T_0 equal the highest and lowest absolute temperatures attainable by the working fluid in the engine. *Q. E. D.*

(To be continued.)

BOILER EXPERIMENTS.

An account of some experiments made in 1873, at the Washington Navy Yard, on the 8 feet diameter cylindrical boiler used with compound engines in several steamers of the United States Navy.

By Chief Engineer Isherwood, U. S. Navy.

As it is necessary in war steamers that the entire machinery be placed below their water line, the height of their boilers in small vessels is, consequently, greatly restricted, and, in many such vessels of the United States Navy, 8 feet were all that could be obtained. When the boilers were to furnish high pressure steam for a compound engine, their shells had to be cylindrical and of this diameter, and it was difficult in so small a circle to obtain a satisfactory arrangement of the furnace and tubes. The plan of boiler finally adopted, is the one shown in the sketch accompanying this paper, and three experiments were made with it at the Washington Navy Yard by Chief Engineers Loring and Baker, of the United States Navy, to determine the effect upon its absolute and economic vaporizations produced by the two modifications of the tube surface and calorimeter hereinafter described. These experiments are the only ones ever made on the evaporative efficiency of boilers of this type with the given proportions, and as several steamers of the United States Navy are fitted with them, it is of interest, in view of a comparison of the cost of the horse-power developed by their engines in pounds of coal consumed per hour, to know the weight of water vaporized per pound of coal.

An important practical evil of boilers of this small diameter at once developed when they were put in use, namely an incorrigible tendency to "prime" or "foam," which required the throttle valve to be nearly always carried very much closed; and, when only a portion of the boilers of a vessel were employed, the smaller that portion, the closer had the throttle to be closed. A very high pressure was thus required in the boiler to furnish a very moderate one in the cylinder, involving all the undoubted disadvantages of high pressure steam, while none of its presumed advantages could be obtained. The excessive strain on the boiler and the excessive temperature in the fire-room, produced by the high pressure steam, were fully realized; but neither the supposed benefit of a large measure of expansion for this very high pressure could be had, nor the unquestionable benefit of a relatively small back pressure against the piston, due to a high average total pressure upon it during its stroke.

The tubes were secured in the tube-plates by means of screw ferrules of brass 1½ inches long, on the outer circumference of which a thread was cut fitting into a corresponding thread cut on the inner circumference of the tube. The ferrule at the back end of the tube had a shoulder which fitted against the outside of the tube-plate, the end of the tube fitting against the inside and forming a shoulder there, so that when the ferrule was turned by means of a wrench on the outside, the shoulders of the ferrule and of the tube were compressed against the tube-plate. The ferrule at the front end of the tube, for the thickness of the tube-plate, had a diameter greater than the outside diameter of the tube, and on the circumference of this greater diameter a thread was cut fitting into a corresponding thread cut in the tube-plate: by means of these threads the ferrule was screwed into the tube-plate, while simultaneously it was screwed into the tube by means of the threads previously described cut on the inner circumference of the tube and on the outer circumference of the ferrule where its diameter was least. By unscrewing the ferrules at both ends of a tube, the latter could be drawn out without injury for examination or cleaning; or for convenience in examining, cleaning or repairing the inside of the boiler shell. This was the purpose of the design which, however, signally failed in the application, as after a short subjection to the high temperature of the gases of combustion, the fittings were so warped and altered that the screws became inoperative, and the removal of the tubes involved the destruction of both them and the ferrules. This very expensive, useless and *un*practical method of securing the tubes in their plates, was originally a French invention and had been tried in the boilers of several French steamers, but its use had long been discontinued before its application to the boilers of any United States Naval steamer.

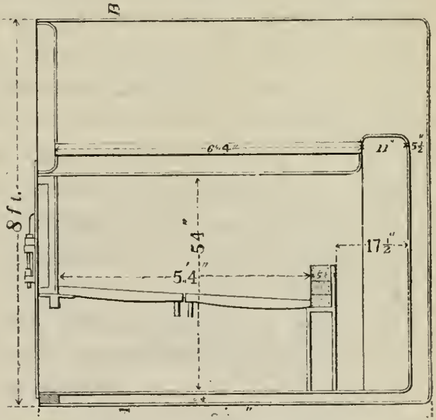
As regards the experiments, it is regrettable that they were not continued for a longer time than twelve hours each, which is far shorter than desirable for reliable results, although, in their cases, great accuracy of observation was depended on to obviate this objection. That the boiler was not protected with the usual non-conducting covering, is also to be regretted, though the writer has been able to satisfactorily supply the deficiency from other data.

The original notes of these experiments were furnished by Chief Engineer Baker to the writer, who has made the necessary calculations from them, and arranged both data and results in a tabular form, prefacing the table with a description of the boiler and of the manner of making the experiments, and following it with some remarks.

BOILER.

The boiler is of the horizontal fire-tube type with nearly all the tubes returned by the sides of the furnace. It is a duplicate of many in use with compound engines on board of U. S. Naval steamers of a small size.

Fig. 1.



Longitudinal vertical section through axis of shell, exclusive of uptake.

The shell of the boiler is a cylinder of 8 feet diameter and 8 feet 1 inch length, with flat ends. The back end is flush with the end ofthe shell, but the front end is recessed 4½ inches within the shell. The entire shell is constructed of ⅝ths inch thick plate iron, with the joints butted, single welted, and double riveted. The front end serves for the front tube-plate.

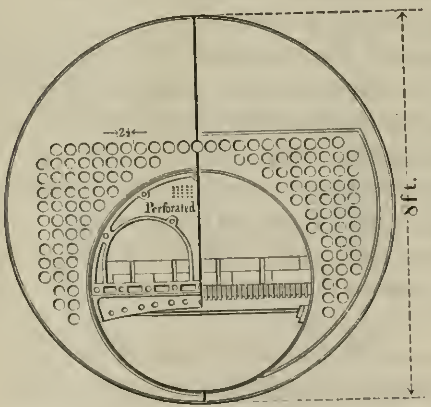
The shell contains a single cylindrical furnace of 54 inches inner diameter and 6 feet 8½ inches extreme length. It contains a grate 4 feet 6 inches wide and 5 feet 4 inches long. The grate-bars are of the ordinary pattern, and are cast in two equal lengths. The grate surface, at the front, coincides with the horizontal diameter of the furnace, sloping downwards 4 inches at the back. The bridge-wall is of cast iron, faced with fire-brick 4½ inches thick on the 9 inches it rises above the back of the grate. The bottom of the ash-pit is 4½ inches above the bottom of the shell. The furnace is constructed of ½ inch thick iron in three equal lengths, and has, at each end of the middle length, a stiffening ring inserted of iron 2½ inches deep, ½ inch thick, and 5 feet outside diameter.

The furnace has two doors placed side by side; each door-opening is semi-circular on top, 20 inches wide and 16 inches high. Each door is perforated with eleven holes of 1⅜ inches diameter for the admission of air; and the lining plate is perforated with as many ¼ inch diameter holes as it will contain, for the distribution of this air above the incandescent coal.

The front of the furnace is of cast iron with a double shell; the outer shell is pierced with seventeen holes of 1⅜ inches diameter for the admission of air; and the inner shell is pierced with as many ¼ inch diameter holes as it will contain, for the distribution of this air above the incandescent coal.

The back smoke connection is 11 inches wide in the clear lengthwise the boiler: it is flat on top, with its sides and bottom concentric with the cylindrical shell of the boiler from which they are separated by a water-space 4½ inches wide including thicknesses of metal. The sides and bottom are, consequently, a segment of a circle 7 feet 3 inches in diameter. The extreme height of the connection in the clear is 5 feet 3 inches. The back of the connection is flat and parallel to the end of the boiler shell from which it is separated by a water-space 5½ inches wide including thicknesses of metal. The connection is stayed to the

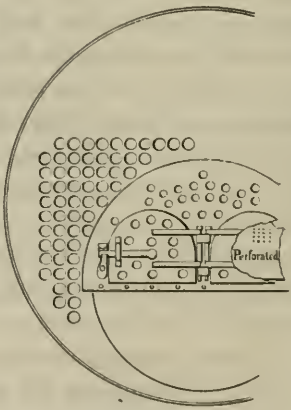
Fig 2.



Half elevation, with uptake and outer plate of furnace front removed.

Half cross section on *A B*, Fig. 1.

Fig 3.



Front elevotion, exclusive of uptake.

boiler shell by socket bolts of one inch diameter spaced every 6 inches. The whole of the connection is of plate iron ⅝ths of an inch thick.

The tubes, with the exception of those of the upper row, twenty-one in number, are divided into two equal and symmetrical groups, one of which is returned on each side of the furnace from the back smoke connection to the uptake, completely filling the spandrels between the furnace and the boiler shell. Of these tubes, sixteen (eight on each end) lie below the level of the top of the bridge-wall, and six (three on each side) lie just at the level of that top, The upper row of tubes lie unbroken above the furnace.

The tubes are of brass and seamless, and are secured to their plates by screw ferrules of 2 inches inside diameter. Each tube is 2½ inches 2·3 inches in inside diameter, in outside diameter and 6 feet 4 inches in extreme length to outside of tube-plates. They are one hundred and nineteen in number. The object of the screw ferrules was to allow the tubes to be removed for cleaning without injury, and to be replaced quickly. The distance between the axes of the tubes, horizontally, is 3½ inches; and, vertically, 3·2 inches.

Above the tubes, the flat ends of the boiler shell are stayed together by eighteen rods of 1¼ inches in diameter: these rods pass through the flat ends, to which they are secured by collars on the inside and nuts on the outside. The rods average 8¼ inches from centre to centre.

The uptake is a separate construction of sheet iron placed against the front end of the boiler, which is nearly covered by it, with the exception of the front of the furnace and ashpit. It has the usual doors, hinged at top and giving access to the tubes for sweeping, etc. The chimney rises from the top of the uptake.

During the experiments, the boiler had no covering of any kind.

The following are the principal dimensions and proportions of the boiler:

Diameter of the shell,	8 ft.
Extreme length of the shell,	8 ft. 1 in.
Number of furnaces,	1.
Width of the grate,	4 ft. 6 in.
Length of the grate,	5 ft. 4 in.
Grate surface,	24 sq. ft.
Number of tubes,	119.
Outside diameter of tubes,	2·5 in.
Inside diameter of tubes,	2·3 in.

Inside diameter of ferrules for tubes,	2·0 in.
Length of tubes in the clear between the tube plates,	6 ft. 2¾ in.
Height of the chimney above the grate surface,	59 ft. 6 in.
Diameter of the chimney connection,	2 ft. 1½ in.
Cross area above the bridge-wall for draught,	6·0945 sq. ft.
Cross area through the tubes for draught,	3·4334 sq. ft.
Cross area through the ferrules of the tubes for draught,	2·5962 sq. ft.
Cross area of the chimney connection,	3·5465 sq. ft.
Heating surface in the furnace,	48·6 sq. ft.
Heating surface in the back smoke connection,	64·0 sq. ft.
Heating surface in the tubes, calculated for their inner circumference,	446·4 sq. ft.
Heating surface in the uptake,	14·0 sq. ft.
Total heating surface in the boiler,	573·0 sq. ft.
Square feet of heating surface per square foot of grate surface,	23·875
Square feet of grate surface per square foot of cross area above the bridge-wall,	3·938
Square feet of grate surface per square foot of cross area through the tubes,	6·990
Square feet of grate surface per square foot of cross area through the ferrules,	9·244
Square feet of grate surface per square foot of cross area of chimney connection,	6·767
Water room in boiler to 6 inches above top of tubes,	100 cub. ft.
Steam room in boiler above 6 inches above top of tubes,	75 cub. ft.
Weight of boiler, exclusive of grate-bars and chimney,	22100 pounds.
Weight of grate bars,	1210 pounds.
Weight of water in boiler,	6233 pounds.

MANNER OF MAKING THE EXPERIMENTS.

The experiments were made in the following manner:

A clean anthracite fire of 9 inches thickness having been brought to steady action, with the steam blowing freely from the boiler escape-pipe—the safety-valve having been previously removed from its seat—the water-level in the boiler was adjusted to 6 inches above the top of the tubes, and the experiment held to commence. Each experiment continued exactly 12 hours, at which time the fire was thoroughly cleaned and made of the same thickness as at the commencement, with the water-level at the same mark.

During the continuance of each experiment, a tabular record or log was kept, in which was noted, at the end of each hour, the height of the barometer, the temperature of the air in the boiler-room, of the feed-water in the tank, and of the gases of combustion in the uptake, the latter being given by a metallic pyrometer. All the anthracite thrown into the furnace was carefully weighed, and all the refuse of ash, clinker and soot was likewise weighed on the same scales. After the completion of an experiment, the tubes were swept together with the other fire surfaces, so that each experiment was begun with a clean boiler. The boiler being entirely new, its water surfaces were quite clean. The water fed into the boiler was first accurately measured in tank. The steam pressure in the boiler was found to be slightly in excess of the atmospheric pressure. All the experiments were made by the same personnel and in the same manner; the anthracite being burned at the maximum rate of combustion which could be obtained without forcing the fire.

The boiler was without any non-heat-conducting covering whatever, and was situated in the still air of the boiler-house of the Steam Engineering department of the Washington Navy Yard. Every precaution was taken to insure accuracy in the results, and, also, that those from the different experiments might be fairly comparable. These results, and the data from which they were calculated, will be found in the following table.

The experiments were three in number. During the first, made on the 24th of May, 1873, all the tubes were in use. During the second, made on the 21st of May, 1873, the lower twenty-one tubes—ten on one side of the furnace and eleven on the other—were tightly plugged at both ends, so as to prevent the passage through them of any of the hot gases of combustion, thereby reducing the heating surface 13·75 per centum, or from a proportion of 23·8750 square feet to 1·0000 of grate surface, to the proportion of 20·5926 to 1·0000; the calorimeter through the tubes being thereby reduced 17·65 per centum, or from a proportion of 1·0000 square foot to every 9·2443 square feet of grate surface, to the proportion of 1·0000 to 11·2255. During the third experiment, made on the 23d of May, 1873, exactly the same reductions of heating surface and of calorimeter were made as in the second experiment, but, in this case, they were effected by plugging tightly at both ends the twenty-one tubes composing the upper row—the plugs used in the second experiment having, of course, been removed from the twenty-one lower tubes. The absolute areas and proportions of the grate surface, heating surface, and calorimeter through the tubes, in both the second and third experiments, were precisely the same, the only difference being that the reductions in these particulars from the quantities in the first experiment, were made in the second experiment in tubes *lying below the top of the bridge-wall,* and in the third experiment in tubes *lying above the top of the bridge-wall.*

The first and second experiments, therefore, permit the determination of the effect produced on the absolute and economic vaporizations of the boiler, by the simultaneous reduction of its heating surface and of its calorimeter through the tubes, its grate surface remaining constant, and all its heating surface lying above the top of its bridge-wall.

In the third experiment, 15·94 per centum of the heating surface, and 21·43 per centum of the calorimeter through the tubes, lay *below* the top of the bridge-wall, therefore, experiments second and third permit the determination of the effect produced on the absolute and economic vaporizations of the boiler by this distribution; the grate surface, heating surface, and calorimeters through the tubes being exactly the same in both experiments, the only difference being in the arrangement of the heating surface and calorimeter through the tubes relatively to the top of the bridge-wall. In the second experiment, all the calorimeter through the tubes was above that top; while, in the third experiment, only 78·57 per centum of the calorimeter was above that top. The grate surface and the calorimeter above the bridge-wall remained constant throughout, and the latter was so much larger than the calorimeter through the tubes that it exercised no influence on the results.

As the boiler, during all the experiments, had no covering to diminish the loss of heat by radiation from the external surfaces; and as boilers on which experiments are made, almost always have very efficient coverings for that purpose; it became necessary, in order that the results from this boiler may be comparable with those from other boilers, to ascertain the vaporizative value of the difference of the heat radiated in still air from the naked boiler and from the same boiler under the same conditions when covered with the usual protector of hair felt $1\frac{1}{2}$ inches thick. This has been effected by means of the constants in a table censtructed from experiments made for this object by the writer, and published on page 161 of the March number of the JOURNAL for 1878. In that table, the number of Fahrenheit units of heat lost per hour per square foot of boiler plate per degree Fahrenheit difference of temperature between that of the steam upon one side of the metal, and that of the still air upon the opposite side, is 2·9330672 when the metal is naked, and 0·2507097 when the metal is covered with $1\frac{1}{2}$ inches thickness of hair felt. The difference, 2·6823575 Fahrenheit units of heat, has been assumed, in the case of this boiler, to have been lost per hour per square foot of the 204 square feet of its exposed external surface, per degree Fahrenheit of difference of temperature between the temperature of the steam inside and that of the still air in the fire-room outside of the boiler. From these data and the latent heat of the steam, the vaporizations in the table due to the loss of heat by external radiation, have been calculated; and these vaporizations have been added to those given by the direct tank measurement, in order to obtain the normal vaporizations. As the experimental boiler was in the same room with other and much larger boilers in use, the temperature of the air in that room has been taken as the proper temperature for the calculation, instead of the temperature of the external air.

RESULTS.

If the atmospheric conditions governing the force of the draught, could be considered constant during the experiments, then the rate of combustion of the gasifiable portion of the anthracite was reduced, comparing experiments first and second $\left(\frac{4148-3625\times 100}{4148}=\right)$ 12·61 per centum for a reduction of 21·43 per centum in the calorimeter through the tubes; that is to say, for a reduction from the proportion of 1·0000 square foot of calorimeter to 9·2443 square feet of grate, to the proportion of 1·0000 to 11·2255: all of the calorimeter in both cases being above the top of the bridge wall. Under these circumstances. the absolute vaporization was reduced

$$\left(\frac{36744{\cdot}067-31919{\cdot}145\times 100}{36744{\cdot}067}=\right) 13{\cdot}13 \text{ per centum,}$$

the economic vaporization remaining sensibly unaffected notwithstanding the reduction of 13·75 per centum in the heating surface. But had the absolute vaporizations been made the same in both experiments, by a proper reduction in the rate of combustion during the first experiment, the economic vaporization would certainly have been at least 6 or 7 per centum better in that experiment with all the tubes in use, than in the second experiment with a considerable portion of them plugged.

In the third experiment, the rate of combustion was sensibly the same as in the second experiment, but the absolute and the economic vaporizations were less. The first fell off

$$\left(\frac{31919{\cdot}145-30103{\cdot}678\times 100}{31919.145}=\right) 5{\cdot}69 \text{ per centum,}$$

and the last, correspondingly,

$$\left(\frac{10{\cdot}202-9{\cdot}680\times 100}{10{\cdot}202}=\right) 5{\cdot}12 \text{ per centum.}$$

If the absolute vaporization in the third experiment had, by means of a higher rate of combustion, been made equal to the absolute vaporization in the second experiment, then this difference of 5·12 per centum in the economic vaporization would have been considerably increased.

With regard to the temperature of the gases of combustion in the uptake during the different experiments, and comparing the first and second experiments, there is a difference of (867·5—814·2=) 53·3 degrees Fahrenheit in that temperature. The rate of combustion in the second experiment was 12·61 per centum less than in the first, but the heating surface was 13·75 per centum less also. Comparing, now, that temperature in the second and third experiments, in which the heating surface and the calorimeter were exactly the same, and the rate of combustion almost exactly the same, the temperature of the gases of combustion in the uptake was (814·2—785·0 =) 29·2 degrees Fahrenheit less in the third than in the second experiment, although 15·94 per centum of the heating surface in the former was less efficient than in the latter, owing to its position below the top of the grate bars. The effect of lessening the calorimeter is to lessen the air supply proportionally to weight of coal consumed, and it may easily be lessened to an extent that will materially affect the completeness of the combustion. Now, as the quantity of heat from a given weight of coal and, consequently, the temperature of the gases of combustion produced, are are lessened in proportion to the incompleteness of the combustion, too

TABLE INE BOILER AT THE WASHINGTON
NA AXIMUM RATE OF COMBUSTION,
H ENDS, FIRST, THE UPPER
THE LOWER 21 TUBES,
SURFACE,

	The lower 21 tubes plugged at both ends; all the other tubes in use.	*The upper row of tubes (21 in number) plugged at both ends; all the other tubes in use.*
	21ST MAY, 1873.	23D MAY, 1873.
	494·2228	494·2228
	20·5926	20·5926
	6·0945	6·0945
BC	3·9380	3·9380
	2·1380	2·1380
	11·2255	11·2255
	12·	12.
	495·060	468·191
	30858·000	29190·000
	1061·145	913·678
T		
QUA	512·084	482·846
	31919·145	30103·678
	4050·	4098·
	425·	486·
	3625·	3612·
	10·494	11·859
	337·500	341·500
	302·083	301·000
RA	14·062	14·229
COM	12·587	12·542
	0·683	0·691
	0·611	0·609
	30·04	29·48
PRI	15·00	14·73
	57·1	77·4
TI	60·0	57·0
A	814·2	785·0
	33114·130	31306·454
	36983·206	34964·320
VA		
IZA		
	8·176	7·639
	9·135	8·667
	9·132	8·532
	10·202	9·680

BOILER EXPERIMENTS.

By Chief Engineer ISHERWOOD, U. S. Navy.

Table containing the Data and Results of three Experiments made on a Single Furnace Cylindrical Marine Boiler at the Washington Navy-Yard, by Chief Engineers LORING and BAKER, U. S. Navy, with Anthracite consumed at the Maximum Rate of Combustion, to ascertain the effect produced on the Economical and Potential Vaporization by plugging at both ends, first, the upper row of tubes (21 tubes), leaving all the other tubes in use; and then plugging at both ends the lower 21 tubes, leaving all the other tubes in use, the upper row having been unplugged. Grate surface, 21 square feet. Height of chimney above grate surface, 59½ feet.

			All the tubes in use.	*The lower 21 tubes plugged at both ends; all the other tubes in use.*	*The upper row of tubes (21 in number) plugged at both ends; all the other tubes in use.*
		Date of Experiment,	24th May, 1873.	21st May, 1873.	23d May, 1873.
BOILER.		Number of square feet of heating surface in use,	573·0000	494·2228	494·2228
		Number of square feet of heating surface in use, per square foot of grate surface,	23·8750	20·5926	20·5926
		Number of square feet of cross area for draught above the bridge-wall,	6·0945	6·0945	6·0945
		Number of square feet of grate surface per square foot of cross area above the bridge-wall,	3·9380	3·9380	3·9380
		Number of square feet of cross area for draught through the ferrules of the tubes,	2·5962	2·1380	2·1380
		Number of square feet of grate surface per square foot of cross area through the ferrules,	9·2443	11·2255	11·2255
TOTAL QUANTITIES.		Duration of experiment, in consecutive hours,	12·	12·	12.
		Number of cubic feet of water vaporized according to tank measurement,	575·247	495·060	468·191
		Number of pounds of water vaporized according to tank measurement,	35862·000	30858·000	29190·000
		Number of pounds of water that would have been vaporized had the difference between the quantities of heat radiated from the boiler when naked and when clad with 1½ inches thick felt been so utilized,	882·067	1061·145	913·678
		Total number of cubic feet of water vaporized in the felt-clad boiler,	589·396	512·084	482·846
		Total number of pounds of water vaporized in the felt-clad boiler,	36744·067	31919·145	30103·678
		Total number of pounds of anthracite consumed,	4568·	4050·	4098·
		Total number of pounds of refuse from the anthracite in ash, clinker and soot,	420·	425·	486·
		Total number of pounds of combustible or gasifiable portion of the anthracite consumed,	4148·	3625·	3612·
		Per centum of the anthracite in refuse of ash, clinker and soot,	9·194	10·494	11·859
RATE OF COMBUSTION.		Pounds of anthracite consumed per hour,	380·667	337·500	341·500
		Pounds of combustible consumed per hour,	345·667	302·083	301·000
		Pounds of anthracite consumed per hour per square foot of grate surface,	15·861	14·062	14·229
		Pounds of combustible consumed per hour per square foot of grate surface,	14·402	12·587	12·542
		Pounds of anthracite consumed per hour per square foot of heating surface,	0·664	0·683	0·691
		Pounds of combustible consumed per hour per square foot of heating surface,	0·605	0·611	0·609
PRESSURES.		Height of the barometer in inches of mercury, corrected for temperature,	29·40	30·04	29·48
		Steam pressure in boiler in pounds per square inch above zero,	14·60	15·00	14·73
TEMPERATURES.		Temperature in degrees Fahrenheit of the air in the boiler-room,	81·4	57·1	77·4
		Temperature in degrees Fahrenheit of the feed-water,	58·0	60·0	57·0
		Temperature in degrees Fahrenheit of the gases of combustion in the boiler-uptake,	867·5	814·2	785·0
VAPORIZATION.	*Absolute.*	Total number of pounds of water that would have been vaporized in the felted boiler had the temperature of the feed-water been 100 degrees Fahrenheit, and had it been vaporized under the standard pressure of 29·92 inches of mercury,	38173·352	33114·130	31306·454
		Total number of pounds of water that would have been vaporized in the felted boiler had the temperature of the feed-water been 212 degrees Fahrenheit, and had it been vaporized under the standard pressure of 29·92 inches of mercury.	42633·551	36983·206	34964·320
	Economic.	Pounds of water vaporized from 100 degrees Fahrenheit by one pound of anthracite,	8·357	8·176	7·639
		Pounds of water vaporized from 100 degrees Fahrenheit by one pound of combustible,	9·203	9·135	8·667
		Pounds of water vaporized from 212 degrees Fahrenheit by one pound of anthracite,	9·333	9·132	8·532
		Pounds of water vaporized from 212 degrees Fahrenheit by one pound of combustible,	10·278	10·202	9·680

small a calorimeter may simultaneously cause both a lessened economic vaporization and a lower temperature of the gases of combustion in the uptake, although, generally, the latter would indicate a greater economic vaporization. The calorimeter through the tubes, which was small in the first experiment, being only the $\frac{1}{9.2443}$ of the grate, was reduced in the second experiment to the $\frac{1}{11.2255}$ of the grate, and, if only that portion of the calorimeter which is above the top of the bridge wall is effective, it was still further reduced in the third experiment to the $\frac{1}{14.2857}$ of the grate. Each of these reductions was probably attended by a more and more incomplete oxidation of the constituents of the coal, owing to a more and more insufficient air supply relatively to the weight of coal consumed. Thus the less and less temperatures of the gases of combustion in the second and third experiments may have have been due solely to their very small calorimeters.

These results show that, with a boiler of this type and of the proportions in the first experiment, both the absolute and economic vaporizations are injuriously affected to a marked degree by a reduction in the heating surface of 13·75 per centum, accompanied by a reduction of 21·43 per centum in the calorimeter through the tubes, the proportion of the original heating surface to the grate surface (23·8750 to 1·0000), and of the original calorimeter through the tubes to the grate surface (1·0000 to 9·2443), being so small that further reductions in either are attended by lessened results. Also, that, other things being equal, both the absolute and economic vaporizations are injuriously affected, and to a marked degree, by placing any considerable portion of the heating surface, and of the calorimeter through the tubes, below the level of the top of the bridge-wall.

Snow Illumination.—During a recent snow-storm, in the early afternoon, an interesting experiment was tried in Paris. At the moment when the sky was darkened by snow, the electric lamps were lighted in the square of the Théatre Francais. The reflection of the light from the snow-flakes immediately dispelled the darkness and produced a very pleasing effect. It is proposed to try a similar experiment in misty weather, and if the light can penetrate even to the distance of 20 metres (65·6 ft.), Jablochkoff lamps will be established at points where the passing is most frequent.—*Les Mondes.* C.

GAUGING AND MEASURING IMPLEMENTS.*

By J. Richards.

It is proposed in the following paper to offer some remarks on gauging or sizing implements such as are employed in machine fitting, and in explanation of some of the tools and processes required in securing precision in such implements.

It will be proper to explain at the beginning that nearly all my remarks, outside of some historical facts, must relate to experiments and results obtained in Philadelphia.

It is, however, thought that in dealing with this difficult branch of manufacture, no harm can arise from some notice of the progress made, especially as the firm of Messrs. Richards, Hand & Taylor, who have furnished the present drawings and examples, do not propose to deal so much with the element of mystery as has been done in some other cases.

For some reasons it would have been preferable to postpone any public notice of this manufacture until a later time, not in respect to implements or machines so much as the qualities of different kinds of material and some of the processes of manufacture, which are not sufficiently determined to be presented in a public essay. At some some future time the subject of material and processes may be brought before the Institute, if thought of sufficient interest.

It is well known to every one connected with engineering manufactures, that the maintenance of uniform or standard dimensions in machine fitting, is fast becoming a rule and almost a necessity, enhancing the value of what is made, and at the same time cheapening the cost of production by permitting a more extended division of labor.

The division of labor in machine fitting, as in nearly all branches of industry, depends on what may be called duplication, that is, producing one thing like another, so that different workmen may, independent of each other, prepare parts or pieces which can be assembled and put together without trying and hand fitting.

It will not be necessary to follow this principle into practical detail until the machines and implements are explained; the matter is alluded to here merely to call attention, at the beginning, to the importance and possible extent of the duplicating system in machine fitting.

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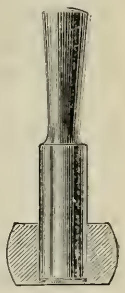
*Paper read before the meeting of the Franklin Institute, February 19th, 1879.

The export of American-made machines to Europe, commenced, we may claim, because of an early and successful application of the gauging system. One of the first and most important orders received from Europe for machinery, was for a nearly complete equipment of implements for the Enfield small-arms factory, in England; machines and tools the main object of which was a duplication of their product. Watches, clocks, sewing machines, small arms, with many other articles of a similar kind, are now made in this country and sold in Europe because the system of gauging and duplicating, offers an advantage overbalancing cheaper labor, cheaper material and more than 3,000 miles of ocean carriage.

Referring now to machine shop gauges, it is well known that most of our larger establishments have been supplied with standard gauges imported from England, usually a set of pins and collars such as are shown in Fig. 1, and corresponding to what is called the Whitworth standard. Most of these gauges are made in the works of the Whitworth company at Manchester, who by long experience and their reputation for good work, have controlled this manufacture. Of late years, however, some fine examples have been made in this country, but at prices much greater than are demanded for English gauges.

Fig. 1.



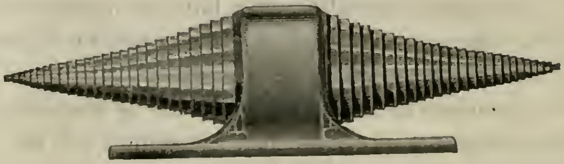
Pins and collars—or cylindrical gauges as they are generally called—were, so far as we have any record, first made by the celebrated John G. Bodmer, of Manchester, a Swiss engineer who may be regarded as the compeer of Sir Joseph Whitworth in machine tool improvement. For thirty years or more these pins and collars have been made with great exactness, the fitting surfaces highly polished and in every respect a marvel of exactness and uniformity.

Before entering upon a description of the tools made and machines employed in the American Standard Gauge and Tool Works in Philadelphia, some history of the origin of the scheme will not be out of place.

In 1860 the writer, while engaged as a manager in the Ohio Tool Company Works, at Columbus, Ohio, feeling the want of some means of maintaining sizes and not having sufficient use for such implements to justify the purchase of a set of pins and collars, conceived the idea of introducing some cheaper system, by which fixed calipers with some simple means to keep them in adjustment, would take the place of pins and collars.

The matter was followed up and calipers of several kinds were made, also a corrective gauge not differing much from the one shown in Fig. 2. In 1867 patents were procured for an improved method of making fixed calipers from steel plates, also for the corrective cone gauge or the standard before mentioned, but circumstances at the time prevented the manufacture of such implements and nothing was done until 1869, when the writer came to Philadelphia with a view of seeking some one to join him in the manufacture of gauging implements. Failing in this, he went to England, partly upon other business, but mainly to gain some information in respect to the manufacture and use of gauges in that country.

Fig. 2.



Investigations there, so far as possible at the time, led to the opinion that a considerable amount of capital would be required, especially in providing machinery for making calipers, and the business was abandoned again until 1872 when, in one of the front offices of the Franklin Institute building, drawings and specifications were prepared for nine special machines to be employed in gauge making. Among these machines were most of those now in use at the works, Twenty-second and Wood Sts., in this city.

A year later, the other front office on the north side, formerly occupied by Mr. Geyelin, was rented for the gauge business, Professor Morton, then Secretary of the Franklin Institute, proposing, if practicable, to fit up a portion of the basement of the building as a workshop.

In 1873, just at the beginning of trade depression, a contract was made with Mr. B. D. Whitney, of Winchendon, Massachusetts, to construct the gauge machines, and they were completed in nine months time, but the state of business was then such that the machinery was packed away as soon as completed and was never set up until August, 1877, when practical operations were for the first time commenced. This was seventeen years from the time the scheme began, but it had been followed in one way or another continually during that time.

It was thought that in a month or so, calipers and corrective gauges would be ready for sale, but these expectations were foiled by several circumstances, principal among which, was the failure of the measuring machine fitted with graduating screws made at the Whitworth Co.'s works in Manchester and guaranteed as to accuracy.

This matter had before been thought of, but there was scarcely a doubt that the pitch of the screws was correct. Subsequent experiments, however, proved that not only the aggregate pitch was wrong and the screws not parallel, but the relative pitch in so short a length as seven inches would not do to depend upon. These screws were, no doubt, as their appearance indicated and as the Whitworth Co. afterwards maintained, carefully made, but the delicacy of measuring tests demands more accuracy than can be attained by relying upon the pitch or movement of screws.

The first experiment in measuring was made by preparing six rods of Stubb's wire, the points nicely finished by stoning and the central part covered with several layers of thick, soft paper to prevent induction. These rods were carefully fitted into the machine when set at six inches, temperature and other conditions being carefully observed. The rods were then uncovered and fitted into a groove cut on the side of a bar of pine wood and taken to Messrs. W. B. Bement & Sons' works, where a Whitworth master screw, with the necessary conveniences for testing the rods, was supplied and even the experiments conducted by the firm, who were kind enough to take a great interest in the matter. By careful comparison it was found that the measuring machine in comparison with the screw recorded about one in ten thousand short. This, of course stopped gauge making for the time. The test rods were then taken to London and in three separate experiments on different standards, two made by myself and one by Gen. B. F. Tilghman, a member of the Institute, it was found that the rods were short, the variation being but little in the three cases and corresponding very nearly with the less perfect experiment at Philadelphia.

The next operation was to procure four standard test rods, adjusted to the Imperial yard of Great Britain and its divisions, by which the measuring machine in Philadelphia could be adjusted. Such rods were prepared in London, with great care, by those having access to the imperial standard, and Mr. George Richards, then in England, brought them out to Philadelphia and began the correction of the measuring machine, proving by combinations of the rods, comparing with Whitworth gauges, and so on. In the mean time, another set of test rods were preparing in Manchester, England, and were forwarded to Philadelphia to prove the first set and also the machine which had then been tolerably well adjusted.

Rods were next adjusted by the Whitworth company at Manchester, and the Standards Department at Washington was visited; in short, all was done that could be done to fix a standard for measurement, and it is now thought that the machine is as nearly accurate as one can be made.

This will be a proper place to explain that the object in seeking for standards in Great Britain was to match what is called the Whitworth scale now in use in our workshops. Many people suppose the Whitworth standard to be an arbitrary and independent one; in fact, this idea is promulgated by the company, because if inquiry is made at the works whether their standard is the same as the Imperial one, the answer will be (or was in one case), "they did not know, they had their own standard." Imagine Sir Joseph Whitworth & Co. preparing gauging implements which did not correspond to the standard of the realm!

A prevalent opinion exists that the British and American standards for lineal measure are not the same. This idea, I have been informed by Mr. John W. Nystrom, came from publications of the Smithsonian Institution,* but a moment's reflection must show how improbable it is that there is any difference in the lineal measures used. The British standard is an arbitrary one, fixed after several years of labor on the part of a learned commission and at considerable expense. The pendulum test, which was the only natural one by which experiments were made, was abandoned after thousands of readings showed its inconstancy. The French metre of the forty-millionth part of the earth's meridian, as well as all other natural standards, were abandoned for the same reason, and the wisdom of this course has been proved by the French government since adopting an arbitrary standard the same as the English had done.

In this country, while there has been more spent in preparing comparative standards than by any other government in the world, there has been no search, so far as I know, after natural or other standards. The equipment of implements of transmission and for measuring, exceeds that of which any other country can boast, but the principal wisdom shown in the matter, has been in avoiding the useless expense of fixing an independent standard which might be anything.

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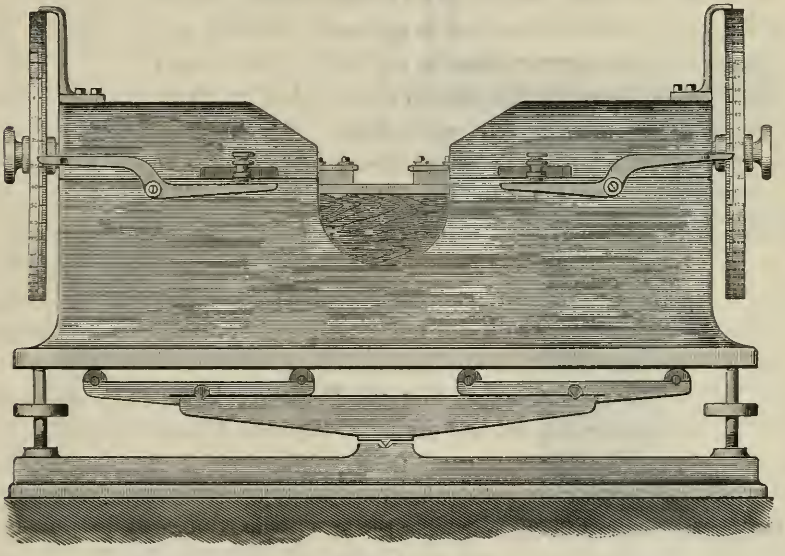
* See "Smithsonian Miscellaneous Collection," vol. i, p. 112 D.

By comparison, under similar conditions, a metal test rod adjusted at Washington and a similar one adjusted at London would show a difference due to ten degrees of temperature, and this is, no doubt, the only difference. It is enough to know that gauges made to a carefully adjusted standard here will match and interchange with those made in England.

Fig. 3.



Proceeding, now, to notice more particularly the measuring machine shown in side elevation at Fig. 3: It consists of a strong frame, on the top of which are two traversing slides very carefully fitted and moved by screws. The contact points seen at the centre are of hardened steel made parallel by careful fitting. The index wheels at each end are to count the revolutions of the screws or divisions of the same. One of the screws has a pitch of eight threads to an inch for the ordinary divisions marked on rules and scales, and the other screw is ten per inch for decimal divisions.

In measuring, the points are brought together in easy contact to form a base or starting point and then expanded by turning one or the other of the wheels, or both, counting the revolutions or parts of revolutions to determine the distance between the points or the size of what is to be measured. On one side the number of divisions is 1000, hence with a screw of ten threads to an inch, each division on the wheel equals $\frac{1}{10000}$ of an inch at the points.

The movable indices on the front of the machine are to correct the imperfections of the screws on a principle which, so far as is known, was invented by Professor John E. Sweet, of Cornell University.

The two set screws seen in front and resting against the upper surface of the index bars are attached to and move with the slides of the machine, and the shape of the surface on which these screws slide may be called a diagram of the screw's imperfections. In the drawing, straight lines are shown, but practically the lines are neither straight nor regular. The wooden throat piece seen below the points is removed when large pieces are to be put in the machine.

The machine is shown mounted on balance bars, which seem superfluous with so strong a frame; nevertheless, by setting up the screws beneath the ends of the frame, a very apparent change in the readings will be seen.

Fig. 4.

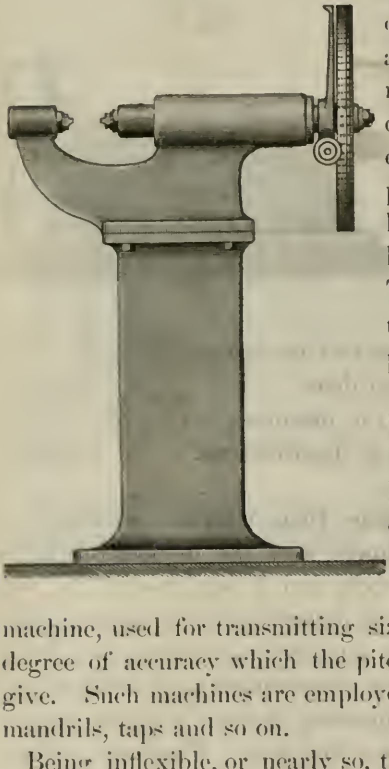


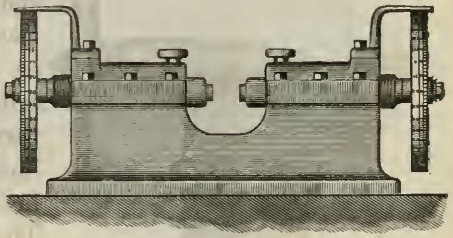
Fig. 4 is what is called a calipering machine, used for transmitting sizes, but not for measuring beyond a degree of accuracy which the pitch of a carefully made screw may give. Such machines are employed in making gauges, reamers, drills, mandrils, taps and so on.

Being inflexible, or nearly so, the accuracy is greater than in using common calipers, but the main difference and that which gives most value to such machines is that they indicate as the size is approached and also variations above or below standard size by $\frac{1}{10000}$ of an inch.

A workman using such a machine has no dread of spoiling his work. He can make a loose fit, a shrinking fit, or a forced fit, as may be required. The value of such a machine in a fitting shop was never conjectured until one was made and put into use at the gauge works.

At first it was intended for use only in grinding mandrils or gauges, but soon became an implement of general use. A workman would finish a piece of turned wook to $\frac{5}{1000}$ or $\frac{10}{1000}$ of an inch in diameter without losing any time. Seeing the value of such a machine, especially for the tool rooms of large machine shops, and also requiring more of them in the gauge works, a smaller and cheaper machine, measuring to 4 in., was prepared. This machine as shown in Fig. 5, is arranged with divisions at one end for the $\frac{1}{5000}$ of an inch and at the other end for $\frac{1}{3200}$ of an inch.

Fig. 5.



The same machine can be adjusted for measuring, if desired, the index points being shaped to correct irregularities of the screws. This is done by experiments and comparison with the standard machine, Fig. 3.

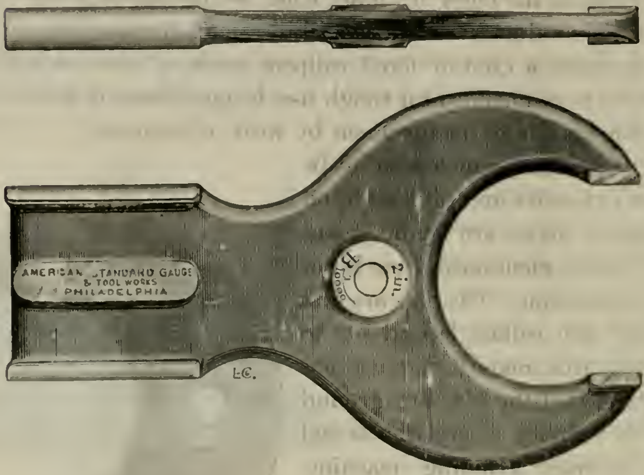
The makers incline to the opinion that machines of this kind will come into general use and are experimenting on various modifications to perfect and cheapen them.

With this much in respect to the machines employed in gauge-making, it will be next in place to describe some of the implements produced.

It was noticed in various shops that, whether provided with cylindrical gauges or not, fixed calipers were the implements in use, in other words, were the working tools, and it was resolved to make these a base, as it were, for gauging, reversing the old system, which would procure the most expensive gauges for reference, and then go downward to calipers and other tools; nevertheless a set of calipers with some means to keep them in adjustment forms a tolerably complete equipment to maintain sizes in a machine shop. There are, in such a case, but few, if any, tools not in practical use, while the original cost is only a fourth to a third as much as under the old system.

After various experiments with moulded steel, it was found to be suitable for calipers. When prepared for the purpose, it would harden the same as cast steel and, when carefully treated, was free from inherent strains. Several different forms were tried, the result being finally to adopt the one shown in Fig. 6.

Fig. 6.

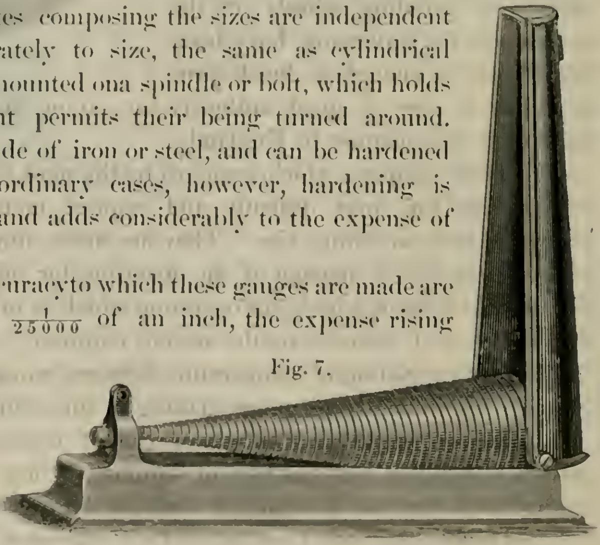


To keep these calipers in adjustment there are furnished what are called corrective gauges, shown in a cheap form in Fig. 2, and in the usual form in Fig. 7. These gauges are like what are called step gauges in appearance, but are made on a wholly different plan. The discs or plates composing the sizes are independent and ground separately to size, the same as cylindrical gauges; they are mounted ona spindle or bolt, which holds them together, but permits their being turned around. These discs are made of iron or steel, and can be hardened if required; for ordinary cases, however, hardening is of noimportance, and adds considerably to the expense of preparing them.

The limits of accuracyto which these gauges are made are $\frac{1}{5000}$, $\frac{1}{10000}$ and $\frac{1}{25000}$ of an inch, the expense rising with the degree of accuracy, but not in the same proportion.

The sizes are usually from $\frac{1}{4}$ to $2\frac{1}{2}$ inches by sixteenths, and from $2\frac{1}{2}$ to 4 inches by eighths of an inch, making 49 sizes, which can be mounted in an iron case, as shown, and be

Fig. 7.



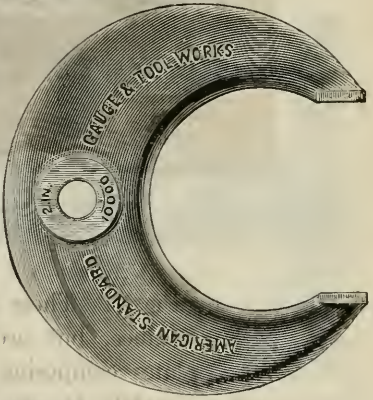
kept in the hands of a manager or foreman, who can at pleasure inspect and test the calipers in use.

If any wear or derangement exists, a caliper can be corrected by a careful blow on the outer or inner edge, as the case may be, requiring but a moment's time, and but little skill after a few experiments.

Fig. 8 shows a kind of fixed calipers, made of steel or white iron; the latter is recommended for rough use, being extremely hard throughout, and not liable to derangement by wear or accident.

Pins and collars, which seem to be the most expensive and difficult kind of gauges to make, are by no means so if, as before mentioned, time is not taken into account. The pins are first made and the collars lapped out to fit; but by this remark it must not be inferred that the pins are ground to size by common emery wheels and in an ordinary grinding machine. Speaking for ordinary practice, this is not the case, because neither the nature of grinding wheels or the movements for traversing, have been found perfect enough to finish pins to size, and there is good authority for saying that none have been finished in this manner in England.

Fig. 8.



The fixed calipers, which seem to be the most simple to make, are nevertheless the most difficult, and require more implements and processes than anything else. They are more subject to change from temperature, and a portion of the grinding for adjustment has to be done on the faces of wheels, an operation which is in all cases extremely difficult, even if accurate results are not required.

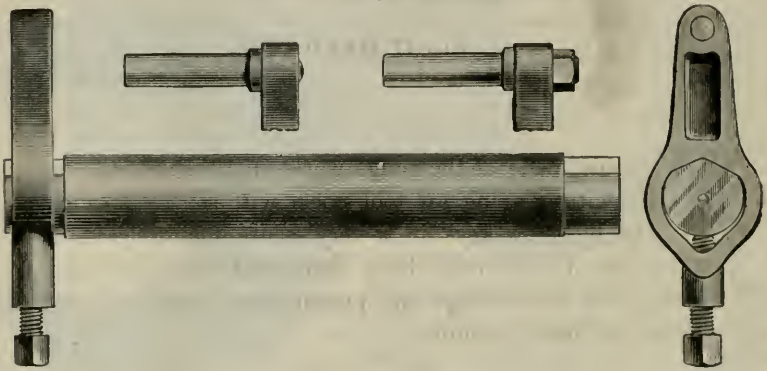
The great variation of temperature between winter and summer is a considerable difficulty in gauge-making in this country.

The lower temperature of winter can of course be controlled by artificial warming, but the heat of summer is not so easily provided against; so that in assuming a scale of temperature, 70° has been adopted at the Standards Department in Washington, and the measuring machine, Fig. 3, has been adjusted at that temperature. In England

62° is the common standard, while in Northern Europe a lower scale is common.

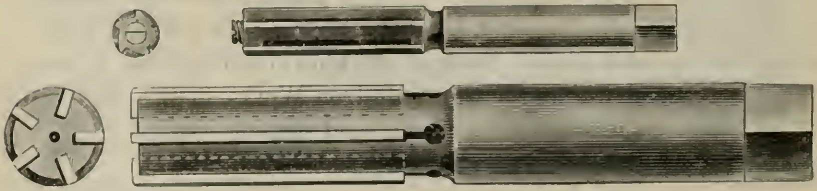
The maintenance of standard sizes in a machine shop involves a good many things beside gauges, but fortunately nothing which should not be provided at any rate. Turning mandrels, for example, must be kept up to correspond. In former times turning mandrels were made of iron, consisting generally of scrap pieces of various lengths, and were usually turned off to fit each time they were used, and on the whole constituted what might be called a nuisance in a machine shop. Now it is evident that if holes are bored to uniform size, one mandrel of each size will do in a tolerably large shop, and if that mandrel is made of steel, hardened and ground to size, the expense of "maintaining it," as we may say, is reduced to a minimum.

Fig. 9.



The engraving, Fig. 9, shows a very good form for mandrels and drivers also. The ends are shaped with two polygonal sides, which fit into a corresponding seat in the driver, as seen in the end view.

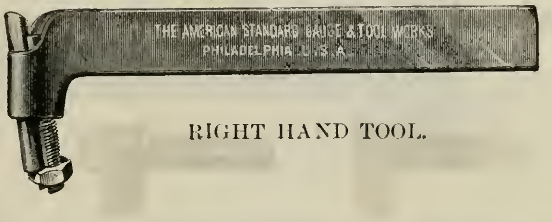
Fig. 10.



The driving studs, as shown on the smaller ones, are separate, and can be removed if not required.

Fig. 10 shows reamers for machine fitting, which can be expanded as they wear away. The smaller one is drilled out centrally, and then mortised between the blades, so that a conical plug forced in by the screw at the end expands the centre of the reamer. The larger one is a blade reamer of the usual type, and needs no explanation.

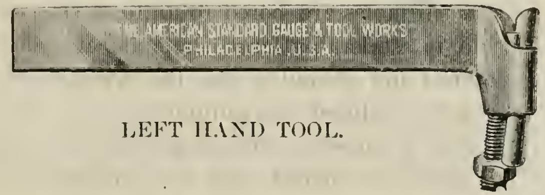
Fig. 11.



RIGHT HAND TOOL.

Among the tools made at the gauge works in Philadelphia, but in no way connected with gauging, are tool stocks with separate or detachable points, held by screw-keys in a very secure manner. A great many modifications of such tools have been tried in this country and also in Europe, but none except the present form seem to have met the expectations of their inventors.

Fig. 12.

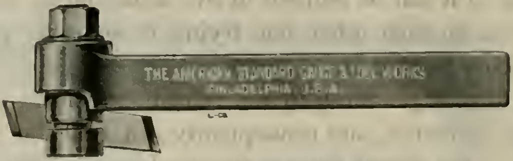


LEFT HAND TOOL.

In Figs. 11, 12, 13 and 14 are shown side views of such tools, those for flat cutting having cylindrical cutters or points, a form not so commonly used here as in England, but having more endurance for heavy cutting than pointed tools. Tools of the kind shown in Figs. 11 and 12 are in general use at the Cornwall Iron Works, in Birmingham, England, where the expense of cutting and shaping iron, in so far as the writer can judge, has been reduced to its lowest limits.

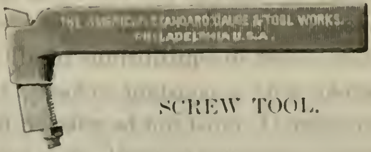
The purposes arrived at in such tools are not always apparent at a first examination, and may be briefly mentioned as follows: (1) The points, being only small pieces, can be made of finer steel than can be afforded for solid tools. (2) The points can be instantly removed or replaced without disturbing the tool stock. (3) The points being duplicates, no time need be lost in sharpening, a fresh point being inserted when necessary. (4) Tool dressing, an expensive and generally unsatisfactory branch, is dispensed with. (5) In grinding the tools a large number can be treated at one time; and there being but one grinding angle and that a constant one, no skill is required in the operation. (6) The height of the point of the tool can be regulated at pleasure, thus avoiding what is called tool raising appliances on engine lathes.

Fig. 13.


THE AMERICAN STANDARD GAUGE & TOOL WORKS
PHILADELPHIA, U.S.A.

SWIVEL TOOL.

Fig. 14.


THE AMERICAN STANDARD GAUGE & TOOL WORKS.
PHILADELPHIA U.S.A.

SCREW TOOL.

The screw-cutting modification will be understood without further explanation, but it may be mentioned that in practice it has proved wholly successful.

The cylindrical point tools are a modification of quite an old invention, originating in Glasgow, and one of the examples shown is from England, where tools of this kind are gradually coming into use.

Mediterranean Tides.—M. Roudaire and Admiral Mouchez have observed tides of 2·5 metres (7·79 ft.) in the Gulf of Gabes. The Venetian tide of ·8 metre (2·6 ft.) is the highest previously observed in the Mediterranean.—*Comptes Rendus.* C.

ON D'AURIA'S ENGINE GOVERNOR.

By the Inventor, PROF. L. D'AURIA.

Whatever may be the scientific principle on which a steam engine governor is constructed, it is easily seen that when in operation all the forces acting on it can be reduced to two acting on its valve in a contrary direction to each other, one trying to shut the passage of the steam, the other to open it.

The first force is produced by the velocity which the engine communicates to the governor, and consequently is a function of the velocity of the engine; the second force is produced by a weight or by the elastic force of some spring.

Let P and Q be respectively those two forces, and W the velocity of the engine; will be

$$P = f(W);$$

and for the equilibrium of the valve, which is supposed to be balanced by the steam, that is, independent of the pressure of the steam, must be

$$Q = P = f(W) \qquad (1)$$

As the pressure of the steam in the boiler, as well as the load of the engine, are subjected to variations, the engine cannot be rigorously governed if the valve is not in equilibrium in all its positions between the limits of its stroke with a constant velocity W of the engine.

Therefore the equation (1) must not be affected by the changes of position of the governor in reference to itself, or it must be independent of the cöordinates of the system constituting said governor. And if the force P is a function of those cöordinates (as takes place in all the governors constructed on the principle of centrifugal force), then, also, the other force Q must be a function of the same cöordinates, but such that the equation (1) results independently of them.

Let, now, H be the friction of the governor, considered at the same point of application of the forces P, Q. The equation of equilibrium of the valve when it moves so as to shut the passage of the steam, will be

$$Q + H = f(W); \qquad (2)$$

and, when the contrary takes place, will be

$$Q - H = f(W) \qquad (3)$$

Subtracting the equation (3) from the other (2), will be

$$2H = f(W) - f(W) = o,$$

which is absurd unless H is equal to zero, or the value of W in the equation (2) is greater than that of W in the equation (3). But in this case, at every change of direction in the motion of the valve, a variation of speed takes place in the engine, more or less, according to the value of the friction H; therefore, to obtain a perfect governor it is not enough that the equation of its equilibrium is independent of the changes of position of said governor, it must be independent also of friction.

Having thus established the conditions to be satisfied in the construction of a perfect governor, my first step toward the solution of this important problem was the elimination of the friction of the valve-stem in its stuffing box, which I consider the most pernicious to the sensitiveness of a governor.

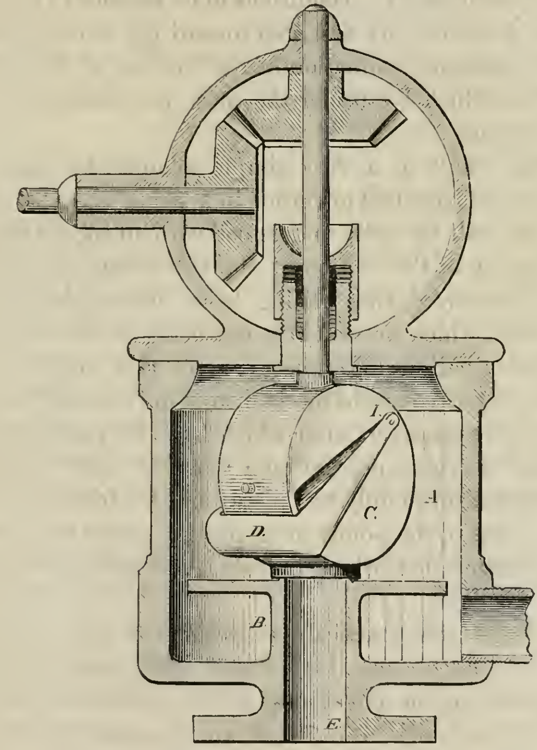
I obtained this result in a very simple manner, by enclosing the mechanism of an ordinary ball governor in a steam chamber in which it revolves. This will be easily understood without special illustration. With the elimination of the friction of the valve-stem, another serious inconvenience is destroyed, that arising from the variable pressure of steam on said stem, which prevents the balancing of the valve.

The use of heavy balls being unnecessary in this improved form, I immediately thought to reduce the mechanism to only one ball and its arm, the valve and its valve chamber; after which I saw the possibility of using the ball arm itself as valve, pivoted on a movable valve chamber, thus reducing the mechanism to only two pieces, and the friction to its minimum, that is, to that of the points of suspension at the ball arm transformed into a throttle valve, which friction is so small as to be neglected in calculations.

One method for the practical realization of my last improvement, which seems to me to exhibit the greatest degree of simplicity in steam engine governors, is fully shown in the annexed drawing (Fig. 1) in which A is the steam chamber having in the centre of its bottom a vertical and cylindrical tube B, open at both ends and prolonged partly inside and partly outside of said steam chamber. C is the movable valve chamber in the drawing, having the form of a short cylindric box or case. It fits the upper part of the tube B, and is fixed on a vertical shaft receiving motion from the engine in the manner shown in the drawing. When this shaft is in motion, it revolves the valve chamber C around its seat B, but without any friction. The ends of the cylindrical valve chamber

C are closed by two parallel walls disposed vertically. On each of them is cut an equal port, conveniently shaped and situated so as to be regulated simultaneously by the oscillating double-weighted valve *D*, composed of two equal slide valves, sector-shaped, rigidly held parallel to each other internally by a bridge *D*, of proper weight, and hung by centre pins on the parallel walls of the valve chamber, so as to oscillate freely on the outside of them in a vertical plane.

Fig. 1.



The stroke of the double-weighted valve *D* is limited to open and shut the ports of the valve chamber without any lost motion. The centre of gravity of the valve is situated below the horizontal plane, passing through the axis of suspension *I*, and the right line joining the mean point of this axis with the centre of gravity, is crossed by the axis of rotation of the valve chamber at an angle of about 45°, so that, when the governor is put in motion the effect of centrifugal force will be to turn the double-weighted valve D on its axis of suspension I, and close the ports on either side of the valve chamber C.

The inside of the steam chamber is divided in two compartments by a disc or diaphragm attached to the shell of the tube B, leaving all around its periphery an annular passage for the steam to flow from the lower compartment to which it is first admitted to the upper one, in which runs the mechanism C, D.

The object of this is the uniform distribution of the steam around C, D without affecting the double-weighted valve D, which, in consequence, is perfectly balanced.

The steam passes from the upper compartments of the steam chamber into the valve chamber through its ports, from which it flows into the tube B, communicating with the engine.

When the velocity of rotation of the mechanism C, D exceeds a certain limit, the centrifugal force raises the valve, the ports of the valve chamber shut, and the speed of the engine falls for want of steam. Then the valve itself falls for want of speed, and the ports of the valve chamber are again opened to the steam, and so on.

Having reduced the friction of my governor to such a minimum as to be neglected in calculations, my attention was directed to find the most convenient manner of suspending the valve, to satisfy as closely as possible the condition expressed in discussing the equation (1), that is, the condition that *with a constant velocity of the engine, the valve must indifferently be in equilibrium in all its positions between the limits of its stroke.*

The following is the calculation made for this object:

Let xx (Fig 2) be the vertical axis of rotation of the governor; C the centre of gravity of the double-weighted valve; y the distance of this point from the axis xx; $T\ T$ the tangent line to the curve described by the point C, touching this same point; θ, the angle formed by $T\ T$ with the axis xx; P, the weight of the valve; F, its centrifugal force, and N the number of revolutions per minute of the governor.

The equation of equilibrium will be

$$F\sin\theta = P\cos\theta \qquad (4)$$

The value of F expressed in function of y and N is

$$F = \frac{P\,N^2\pi^2 y}{900 \times g}$$

Substituting it in the equation (4), after reductions will be found

$$\frac{N^2 \pi^2 y}{900 \times g} tang\theta = 1 \qquad (5)$$

or

$$y tang\theta = \frac{900 \times g}{N^2 \pi^2} = Const: = C$$

If the axis xx is considered as axis of abscissas of the curve described by the point C and y as an ordinate of the same, will be

$$tang\theta = \frac{d\,y}{d\,x}$$

Substituting this value in the last equation, will be

$$ydy = Cdx;$$

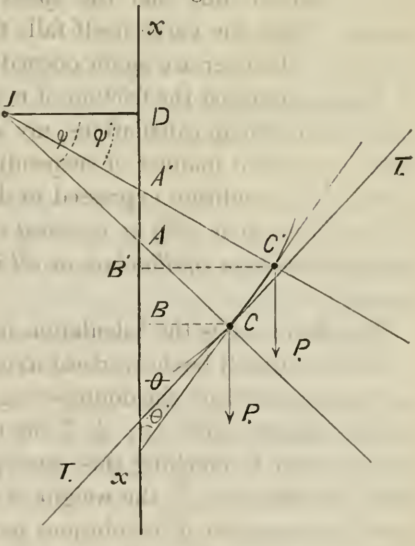
and

$$\int ydy = C\int dx;$$

or,

$$y^2 = 2Cx$$

Fig. 2.



This equation represents a parabola; therefore, to satisfy mathematically the above-mentioned condition, the point C must move on such curve.

I could obtain this effect practically by suspending the valve with a chain, which develops from a parabolic outline, it being known that the evolute of a parabola is another parabola. But, as the oscillation of the valve is short, the parabolic arc described by C can be considered approximately as an arc of circumference having for its centre the mean centre of curvature of said parabolic arc; and this centre be considered as point of suspension of the valve.

Now, as the co-ordinates of this point are

$$\text{Abscissa} = c + \frac{3y^2}{2c}; \qquad \text{Ordinate} = -\frac{y^3}{c};$$

it is evident why the axis of suspension I, I, of the valve, is situated, as shown in Fig. 1, in reference to the centre of gravity of said valve and the axis of rotation of the valve chamber.

But this disposition is not at all arbitrary, as it seems to be, because the axis of suspension I, in reference to its position and its distance from the centre of gravity C, can be determined by calculation so as to obtain the equilibrium of the valve in all its positions with the smallest variation of N; that is, with the smallest variation of speed in the engine.

In fact, let IC, IC^1 (Fig. 2) represent the extreme positions of the valve; φ and φ^1 their respective angles with the horizon; and let

$$ID = a; \quad IC = IC^1 = R;$$

$$\therefore \qquad y = CB = R\cos\varphi - a$$

$$y = C^1B^1 = R\cos\varphi^1 - a.$$

Substituting successively those two values of y in the equation (5), observing that $\varphi = \theta$, $\varphi^1 = \theta^1$, will be found, after reductions,

$$\left.\begin{aligned} N^2 &= \frac{C}{R\sin\varphi - a\tan g\varphi} \\ N^2 &= \frac{C}{R\sin\varphi^1 - a\tan g\varphi^1} \end{aligned}\right\} \quad (6)$$

Now, it is easily seen, that if

$$R\sin\varphi - a\tan g\varphi = R\sin g\varphi^1 - a\tan g\varphi^1; \qquad (7)$$

or,

$$R = a\frac{\tan g\varphi - \tan g\varphi^1}{\sin\varphi - \sin\varphi^1}$$

the valve will be absolutely in equilibrium at its extreme positions without any variation in the number N, or of speed in the engine.

For the intermediary positions of the valve, theoretically, the number N is not constant; but its variations are so small that it can be considered practically as constant.

The members of the equation (7) represent, respectively, in Fig. 2, the distances $A\,B$, A^1B^1, that is, the projections of $A\,C$, A^1C^1 on the axis xx; therefore, those two projections must result equal to each other in the drawing.

Gallium Battery.—J. Reynauld has succeeded in making a battery of liquid and solid gallium by means of a metal solution of gallium sulphate. The liquid metal takes the place of zinc; the solid, of copper; the former being negative in relation to the latter.—*Fortschr. der Zeit.* C.

CONICAL ARCHES AT SOUTH ST. BRIDGE, PHILA., PA.

By D. McN. Stauffer, C. E.*

The Eastern approach to South St. Bridge in this city is made up in part of a somewhat peculiar piece of arch-masonry, and as it contains certain novel features, that might be applied with advantage at other points, we will attempt to briefly describe it.

The centre lines of South St. and the bridge proper intersect each other at an angle of 33° 25′ necessitating a curve in the approach from the East, and to conform in design with the "late lamented" Western approach, this curve was pierced by three arches.

The ordinary practice in arches on a curve is simply to widen the pier ends towards the outside of the circle, and leave the arches themselves "right arches." But it was thought here that the work could be much improved in appearance and a considerable saving in masonry and foundations attained, by leaving the piers of the same thickness throughout, and throwing the eccentricity into the arches, and to this end the following plan was determined upon, after due deliberation and numerous experimental plans.

The foundations of all the masonry in the Eastern approach were upon hard gravel—timber platforms supporting the masonry—but as this gravel stratum communicated directly with the river, and was from 12 ft. to 15 ft. below high tide; the foundations were expensive, and any reduction possible in their extent was an item well worthy of consideration.

The roadway of the approach was 55 ft. wide from out to out, and the centre line of the curved portion, which curve was entirely occupied by the three arches, was located with a radius of 169 ft. 6 in, with an included angle at centre of 33° 25′. The abutments of the arches were consequently upon the tangents to the curve.

Each one of the two arch piers was 55 ft. long, 5 ft. 6 in. thick, throughout, and 12 ft. high from foundation to the springing line of the arch. The material used in these piers was Port Deposit granite, rock-face ashlar, cut in courses of from 17 in. to 27 in. rise, with "through headers" liberally distributed throughout the length of the pier. The Skewback and coping, forming one piece was of Maine granite, hammer-dressed, and nearly every other section extended across the pier, making a double skewback, the sections averaging 4 ft. in width.

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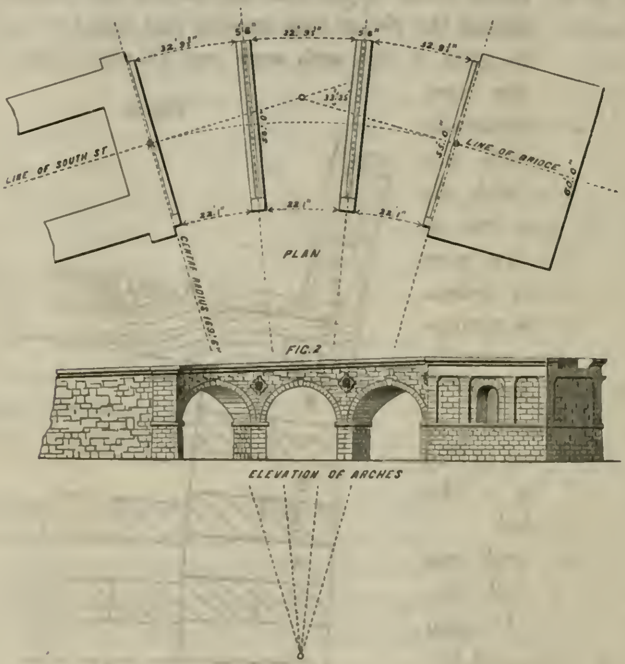
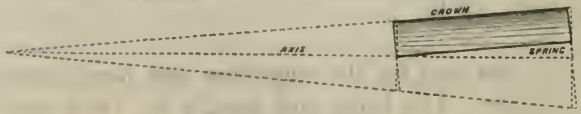
* A paper read before the Engineers' Club of Philadelphia.

The centre line of each pier was located on a radial line of the curve, the sides of the pier being parallel to this radius, and 2′, 9″ distant from it. The bounding radii of the curve fell in like manner 2′ 9″ inside the abutments, making the plan of the three arches equal, and in dimensions as follows: Each arch was 55 ft. long, the chord span at the inner end 22 ft. 1 in., and at the outer end 32′ 9¾″. The

Fig. 1.



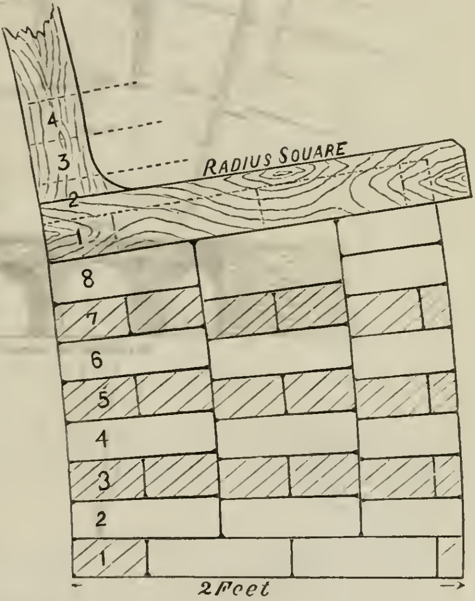


rise of the arch was 11 ft. ½ in. throughout, the springing line and crown of the arch being both horizontal.

This arch is really a portion of a cone, and may perhaps be better described as follows: The line of the *crown* of the arch would fall in the "slant height" of the cone, and the plane of the *springing line*, would be a plane parallel to the slant height, and cutting the axis of the cone at the point which represents the face of the smaller end of the arch, thus making the rise at that smaller end equal to one half its chord span. The ends of the arch were cut at right angles to the slant height of the cone, and would be theoretically ellipses, but in this case the angle made with the axis of the cone was so nearly 90° that they were treated as circular arches. The fact that the springing lines were actually the flatter portions of a parabola — instead of straight lines—was in like manner, and for a like reason, disregarded.

The smaller arch was regarded as a full centred arch of 22′ 1″ span and 11′ 0½″ rise, and the other as a "segmental" arch of 32′ 9⅜″ span, and 11′ 0½″ rise.

Fig. 2.



Maine granite was used for the ringstones and hard burned brick for the arch proper. The brick ring was 24 in. thick, and laid in cement mortar, formed of one portion Rosendale hydraulic cement and one part clean sharp river sand. The bond used in the brickwork can be better understood by an examination of the accompanying Fig. 2. The advantages of this bond were as follows: First and most important, by this arrangement, the thickening of the mortar joint as the extrados of the arch was approached was confined to the *length of one brick*, and this would be the case no matter how thick the ring, 2d. The arch was divided in its length into a series of true voussoirs, the bond repeating itself in each 8 courses. And 3d. The intrados of the arch was uniform in appearance, the bond being a "header and stretcher bond" everywhere; in case of any settlement and consequent cracking of the arch, bricks arranged as these were could not fall out of the arch as readily as in a bond formed of a *series* of headers and a *series* of stretchers alternating, a common form of arch masonry.

The arch centres were built of 8″ × 8″ white pine timber and 2 in. plank, bolted together with 1 in. bolts; they were spaced 5 ft. apart from centres of ribs, and covered with a 2 in. planed lagging. The chord span of each rib, in the length of any one arch, was of course different from the rest, and to insure accuracy in this point, each rib was struck out upon a platform separately and framed on this platform. The ordinary "double wedge and key" was used in striking them.

One end of the conical arch being treated as a "full centre" arch, and the other as a "segmental" arch, the skewback joining them would be in theory a winding surface. But as economy of cash was the governing principle in this work, advantage was taken of the use of brick in the arch, and the skewback was made to approximate to theory by dropping the top of each section, say every four feet, one half inch below its neighbor, and cutting the face of the skewback to suit, cut without a "twist." In this way a series of slight steps was formed, passing from a radius of 2 ft., and a sine of 10 in. at the segmental end, to zero or a horizontal plane, three feet back of the full centre arch.

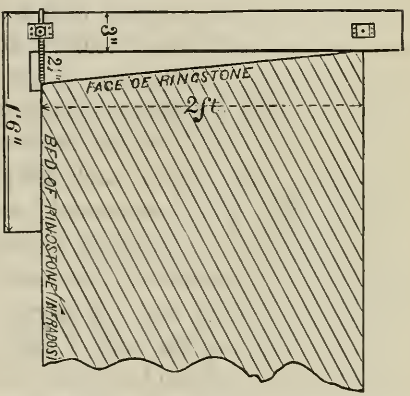
As the ringstones had all to be laid on lines radiating from the apex of the generating cone, the angle formed by the *face* of each ringstone and the *intrados* of the arch was one uniformly but constantly varying from the key to the springing line. The keystone was the only one in which this angle was just 90°. In the segmental arch the angle *increased* from 90° at the crown to 95° 20′ at the spring, and at the full centre end the angle *decreased* from 90° at the crown to 84° 40′ at the springing line. Each ringstone taken in the direction of its length was wedge-shaped, with its face wider or narrower than its back as it was located in the segmental or full center end of the arch.

As the curved portion of the approach was finished on top with a finely cut granite coping set on a regular curve, the ringstones had to be laid on the centres to fit this vertical curve, with its radii of 197 ft.

and 142 ft. respectively. The versed sine, or the horizontal distance between the extreme point in the horizontal curve of the arch face at the *crown*, and a chord line drawn at the *spring* of the arch, was at the segmental end 9 in., and at the other end 5 in. nearly.

All the granite work in these arches, except that used in the piers, was cut at the quarries in Maine, and to avoid the necessity of making and shipping a zinc pattern to conform to each face angle in the two sets of ringstones required, the following plan of giving these angles was devised. It was simple and worked well in practice.

Fig. 3.



An ordinary stone-cutter's square of iron was provided with a sliding graduated bar, and a set-screw as shown at Fig. 3. A separate bar with its proper graduations stamped and numbered upon it was provided for the two ends of the arch, there being 43 ringstones in the segmental arch and only 35 in the full centred arch. When used, the bar was placed at the *top* of the square when the face angle decreased from a right angle, and at the *bottom* when this angle was more than 90°. As each stone was cut it had a number and a letter painted upon, denoting its position in the arch, so that they were readily put in place. We should add that as the angles varied uniformly, a length on the bar equal to the tangent of the angle of greatest variation, from a perpendicular to the bed of the stone, with a radius of two feet, was divided into as many parts as there were ringstones between the springing line and the key. The ringstones were rock face with 1½″ draft, and the offset between any two adjoining ringstones was so slight that no attempt was made to conform to the winding face surface that theory required. The "pointing" was so managed as to hide the slight variation that did exist. The bed of the ringstone was first cut to a zinc pattern, then the build, and finally the face angle obtained with the square as above described.

The haunching of the arches was built of well-bedded lime stone from the Conshohocken quarries, laid dry, and thoroughly grouted, with one part Rosendale cement to two parts of sharp sand, at every $2\frac{1}{2}$ ft. in height. The foundations were of the same stone, laid in cement mortar.

From the foregoing description it will be seen that strict theory was in all cases sacrificed, whenever it could be done without injury to the stability of the work, and much money was saved thereby. The final result was a piece of arched work that has stood perfectly in all its parts, and while possessing many advantages in appearance, really cost less than the more clumsy form, often adopted in similar cases.

GRAPHIC FREIGHT DIAGRAMS.

At the meeting of the Franklin Institute, Mr. P. H. Dudley presented his method of constructing diagrams showing graphically the cost of moving freight for a particular railroad, of which the following is a brief description:

The general basis of estimate being the cost of moving the entire tonnage of freight cars, locomotives and cabooses, of the freight department, for one year.

The expenses of doing the business of a railroad were considered as formed by the operation of two distinct principles, viz.:

1st. Those which were independent of the volume of business done, such as expense of organization for a prospective business, interest on debts, taxes and the general depreciation of the plant by natural causes, which were termed permanent operating expenses.

2d. Those which were dependent upon the amount of business done, such as fuel, repairs to plant due to service and increased help, which were termed direct operating expenses. Owing to differences in organization and method of doing business, each railroad will vary in some of the details of classification.

The various expenses per ton per mile, so classified, were plotted on cross section paper, the abscissæ or horizontal lines representing the tonnage, and the ordinates or vertical lines the cost in dollars and cents, each noted per car. Taking the direct operating expenses per ton per mile, and plotting the results, the ordinates increase regularly; drawing a line through them it rises obliquely from the axis. Now, plotting the sum of the average permanent and direct operating expenses per ton per mile, and also a rate per ton per mile, we have a means of comparing the rate with the cost per ton per mile. When the plotted rate line falls entirely below the direct operating expenses for the usual length of train, then all business is done at a loss, consequently the greater the volume the greater the loss. When the rate line is below the two expense lines, then the excess above the direct operating expense line tends to reduce the permanent operating expenses (which must be entirely overcome before any net earnings are made). In this case, the greater the volume of business the less the loss. Any special business which gives a rate over the direct operating expenses should be considered. When the plotted rate goes above the sum of both expense lines, the excess shows the net earning per ton per mile, based upon a like volume of business. If the volume has increased, the permanent operating expenses will be decreased, but when the volume is decreased the expenses will be increased per ton.

When the cars are to be returned empty, the direct operating expenses of moving both ways must be added together and plotted as for one way. On foreign cars, the car service must be added before comparing with the rate line. The distribution of expenses by the car for trains, gives curved lines showing that within the limit of train lengths, the expense decreases per car. The oblique lines also show the economy of long trains, as each car tends to reduce the cost of moving the tonnage of the locomotive and caboose. Various items of expense are plotted in detail. A difference of $\frac{1}{1000}$ of a cent in the rate will show. Many of the elements of the expenses were determined by the use of the dynograph.

Stability of Verticals.—Mouchez and Gaillot, the astronomers who computed the intra-Mercurial orbits which agreed so closely with harmonic prediction, have turned their attention to the mooted question whether vertical lines are changeable. As a preliminary result, they find that there are extreme differences of nearly a second of arc; that the variations from the mean are greatest in summer and in winter; that they are probably due to temperature, either through influences on the instruments or on astronomical refractions. The researches, which are very delicate, are still in progress at the Paris observatory.—*Comptes Rendus.* C.

Continuous Railway Brakes.—In the course of his experiments with railway brakes, Captain Dingles Dalton has among other things clearly proved that the brake force required to produce the maximum effect varies according to the speed. It must be very great when first applied and then must be reduced as the speed decreases so that skidding may be avoided. He also concluded that this could best be accomplished by utilizing the friction between the brake blocks and the wheels, for regulating the pressure by which that friction was produced. Quite recently he has made some experiments with a new valve design by Mr. Westinghouse, for the purpose for reducing the pressure and set in action by the brake pressure. This valve was found to give very promising results, and to reduce the pressure in accordance with the requirements, except at the last moment before the train was brought to rest, when, in consequence of the discharge aperature being rather too small, the air could not escape from the brake cylinder quite quickly enough to avoid in every case a slight final jerk. In the former experiments the best results could only be obtained by carrying the exact amount of pressure which was required for the speed from which the stop was made, and which in every case had been previously determined; and the pressure was reduced, as the train speed fell by the manipulation of the temporary reducing valve. When the initial pressure was accidentally too high, or when it was not reduced soon enough, skidding was always produced, with corresponding loss of efficiency. In the present experiments, it was found that, however great the initial air-pressure, the new valve would not allow too much force to be exerted against the blocks, so that an initial pressure which in ordinary circumstances would have produced immediate skidding was rendered unable to do so. The diagrams of the brake-block pressure, taken with the valve in use, show exactly the force required at all speeds, or the very point which it was hoped might be determined by the earlier experiments. By the use of this simple contrivance, maintained in action by the friction of one of the brake blocks, more information has been gained in a single day with regard to the amount of brake power which should be applied at any given speed than in the whole of the former experiments, which were continued over nine days. Twelve stops were made by slipping the van from the engine, and the reducing valve was changed several times, so as to be opened by a greater or less amount of friction. The results obtained were as follows:—Speed in miles per hours, and yards run before stopping—45 and 96; 53 and 171; 55 and 171; 55 and 141; 60 and 171; 60 and 167; 62 and 176; 54 and 227; 55 and 195; 57 and 206; 57 and 223; 60 and 214. The last five stops on the above list were made with the valve so adjusted as to be opened by a brake-block friction which would not produce skidding even on a wet rail, while in all other cases it was so adjusted as to produce the greatest amount of retardation on a dry rail. The action of the valve was such as to render it apparent that its employment in ordinary traffic, when perfected for this purpose, would be of great practical utility. The air was heard to escape continually, and the valve was highly sensitive. If an appliance of this kind, so simple in its construction and so certain in its operation, were attached to every vehicle, and were so set as to open before the adhesion attainable on a wet rail was exceeded, it would become immaterial whether the driver maintained only a certain pressure for a certain speed, or whether he carelessly applied his brake with a high pressure when running at a low speed. The valves, already adjusted for the required amount of retardation, would act of their own accord, and would only allow the proper degree of pressure to be exerted by the brake-blocks. The stops would then always be made within given distances for given rates of speed.—*Iron.* *

Telegraphing to Running Trains.—C. M. Gariel describes the successful working of Baillehache's invention for signalling to and from trains in motion, on a part of the line which connects the Champs de Mars with the station at Grenelle. The experiments were so successful that they are likely soon to be repeated on a much larger scale. —*La Nature.* C.

Changes of Spectra.—If a small quantity of mercury is placed in a hydrogen Geissler tube, E. Wiedeman finds that an induction current gives the hydrogen spectrum at ordinary temperature. But if the tube is warmed in an air-bath, as the temperature rises the mercury lines appear, while the hydrogen lines grow fainter and finally disappear. If a tube of hydrogen and nitrogen is warmed at any point, so as to free sodium or other metals from the glass, the hydrogen and nitrogen lines vanish almost entirely while the lines of the metal appear. Does the hydrogen disappear, or is it transmuted into some other substance?—*Comptes Rendus.* C.

American Bridge-building.—In an address upon the public works of the United States, M. Malezieux compliments the American engineers upon their skill in building bridges of large span, and says that all other nations may borrow many useful hints from them in regard to the use of compressed air in laying foundations.—*Ann. des Ponts et Chauss.* C.

Interesting Experiment.—On the 4th of August, Pasteur enclosed some vine-sets in hot-beds, almost hermetically sealed. The grapes ripened about Oct. 10th. Grapes that had ripened in the open air fermented in less than 48 hours, in a temperature varying between 25° and 30° (77° to 86° F.), but those that ripened under glass remained unchanged. This result, which had been predicted by Pasteur, lends strong confirmation to his views.—*Comptes Rendus.* C.

Japanese Coal Beds.—The Japanese government has offered a liberal subvention for the development of the coal basin in the island of Yesso, where the supply is said to be sufficient to furnish, for a thousand years, as much as is now mined in Great Britain. The apprehension, which is already felt from the competition of the Mongolian races, will be still more reasonable when they have felt the full use of the principal element of European industrial wealth.—*Les Mondes.* C.

Delicate Measurements of Contacts.—C. M. Goulier states that if the eye is so placed as to see the ivory point of a Fortin barometer in the same direction as the image of the cap which the mercury reflects, while the rest of the surface reflects the sky, the naked eye can readily distinguish the slightest indentation of the point into the mercury. By experiments with a vertical micrometric vise, he found that he could estimate the contacts within less than $\frac{1}{300}$ of a millimeter (·00013 in.).—*Comptes Rendus.* C.

Ancient Milanese Aqueducts.—In making excavations for a new system of sewerage, E. Bignami Sormani has found well-preserved remains of two ancient aqueducts, which were evidently used for conveying fresh water, probably for the supply of fountains and other domestic uses in early palaces or villas. The pipes are of terra-cotta, and Sormani is inclined to refer them to the time of the Roman Empire, the form, mode of construction and general details being indicative of a great antiquity.—*Il Politecnico.* C.

Soluble Glass in Bronzing.—Böttger varnishes objects of wood, porcelain, glass or metal with soluble glass and then shakes bronze powder over them.—*Dingler's Journal.* C.

Bleaching Diamonds.—Ch. Riballier recommends heating grey or brown diamonds with carbonate of lime and powdered coal in air-tight crucibles, and allowing them to cool slowly.—*Ding. Jour.* C.

Rotating Steam-Engine.—A. Müller, of Cologne, connects a number of turbines in a common casing, the diameter of the turbines gradually increasing. The steam enters the smallest and escapes from the largest. This contrivance is said to be very economical either for steam or under a head of water.—*Dingler's Journal.* C.

Retention of Heat.—M. Degremont glues upon cloth a series of small segments or rods of wood to form a sheathing for steam pipes. It has the advantage of being easily removed and replaced, which is not the case with most heat retainers. Small, round-headed nails are used to prevent contact between the wood and the pipe, and to enclose a layer of air between the pipe and the sheathing.—*Bull. de la Soc. d'Encour.* C.

A New Element.—Marc Delafontaine announces the discovery of the oxide of a new metal, to which he gives the name of Philippium [Pp.] in honor of his benefactor, Phillipe Plantamour, of Geneva, the friend and pupil of Berzelius. He is pursuing a comparative study of the compounds of Philippium and of Terbium, and he proposes soon to publish a memoir in which he will describe the processes of preparation and purification.—*Comptes Rendus.* C.

A Silver Mill in the Clouds.—The largest and best arranged silver mill ever made has been lately built by the Pacific Iron Works, of San Francisco, for the Cerro de Paseo Mining Company, in Peru. It has 80 stamps, weighing 900 lbs. each ; 44 five-foot amalgam-pans ; 22 nine-foot reservoirs, with all the belongings of the newest and best kind. It is made in sections, with no single piece heavier than 500 lbs., because it must be carried by mules over very steep paths, about 150 miles east of Lima, to a height of more than 14,000 feet. There are 17,000 pieces altogether, having an aggregate weight of over 600 tons. The whole mill was built and shipped inside of fifty days. The Cerro de Paseo mines are the richest and most famous in the world, having already yielded more than $500,000,000 worth of silver.—*Der Techniker.* C.

Large Steam-Pump.—Pittsburgh has the largest steam-pump in the world. It weighs 1500 tons, cost $423,350, and pumps 14,240,000 gallons of water per day. Those next in size are one at the Lehigh Zinc Mines, with a service of 3,450,000 gallons, and the two Chicago pumps, with a service of 4,500,000 gallons.—*Der Techniker.* C.

The Microphone as a Thief-Catcher.—An Englishman in India, finding that his oil disappeared with wonderful rapidity, attached a microphone to the can, with a wire leading to his bed chamber. Soon after he had closed the house for the night, he heard a gurgling noise, and, running quickly down stairs, he caught the thief in the act of filling his own flask from the can.—*Der Techniker.* C.

High Trees.—The highest sequoia tree in the United States is in Calaveras grove, near Stockton, California. It is 325 feet high. A eucalyptus was once felled in Australia which was 500 feet high, with a circumference of only nine feet. Near Fernshaw, in the Danderong District, Victoria, an "almond-leaf gum" (*eucalyptus amygdalesius*) has lately been found which measures 380 feet from the ground to the first branches and 450 feet to its top, thus exceeding the California tree by 125 feet.—*Der Techniker.* C.

Constitution of Nebulæ.—In the "Investigations upon the height of the atmosphere and the constitution of gasiform cosmical bodies," A. Ritter deduces the following law: "If, in consequence of increase or diminution of heat, the radius of the gaseous globe undergoes a change, the temperature of its centre also changes; but the product of the radius into the central temperature is constant." If p, v, T, respectively, designate the pressure, specific volume and absolute temperature of a definite, minute portion of the body, $pv^{\frac{4}{3}}=$ constant; $Tv^{\frac{1}{3}}=$constant; $\frac{T^4}{p}=$constant. Since Neptune's orbital radius is about 6,000 times as great as sun's present radius, according to the above law the sun's central temperature is now about 6,000 times as great as when, according to the Kant-Laplace hypothesis, the sun was expanded to the orbit of Neptune. Of the whole work which has been performed by gravity during that immense interval, more than four-fifths is still stored within the sun's mass in the form of heat.—*Ann. der Phys. u. Chem.* C.

Purification of Fatty Waters.—Prof. F. Hetet has described his automatic apparatus for the purification of fatty waters by lime water both for the purification of boilers and for making distilled water drinkable. The French Navy Department has adopted his method for all boilers with surface condensers.—*Bull. de la Soc. d'Encour.* C.

Parallel Pincers.—Robert Muencke, in *Dingler's Journal* (1878, 230, 36), describes a useful contrivance for holding retorts, alembics, tubes, etc., in chemical laboratories. They are made on the principle of the parallel vise. Their close grip and the various uses to which they may be applied will doubtless give them a wide popularity. C.

Harbor of Alexandria.—Alexandria has the largest artificial harbor in the world. The outer breakwater is two miles long; a tongue of land curves around the harbor, so that there is no exposure to the winds and waves, except the straight and deep canal which serves as an entrance. The solidity of the breakwater, quays and jetties does great credit to the contractors, who finished the whole in eight years. —*Les Mondes.* C.

Stability of Molecular Systems.—In discussing the constitution of matter, Wurtz describes the various movements of vibration, rotation, gliding, rectilinear progression and orbital revolution, to which the atoms and molecules of all bodies, solid, liquid and gaseous are continually subjected. To the question whether all these varied and continual motions are not sources of instability, he answers: Quite the reverse. If the atomic aggregations were immovable, they would be more unstable than they are while moving; the familiar example of the bicycle illustrates the influence of motion on the stability of equilibrium.—*Bib. Sci. Internat.* C.

Allotropy of Metals.—M. Schützenberger, in his investigations of the different molecular states of metals, finds that other metals than antimony, especially copper, lead and silver, take allotropic forms when precipitated from saline solutions, by electrolysis or otherwise. He predicts that this will prove to be the case with a large majority of metals. The less active and more stable modification is formed at the expense of the other, with loss of heat, like red phosphorus from ordinary phosphorus, or oxygen from ozone. Allotropic copper, when oxydizing in the air, takes brilliant rainbow hues, which may have a valuable industrial application.—*Bull. de la Soc. d'Encour.* C.

Interpretation of Imaginary Roots.—M. Appell shows that, in some cases, the imaginary roots of time-equations, in mechanics, represent a simple reversal of the direction of the constant force.—*Comptes Rendus.* C.

Renewal of Files.—The application of Tilghman's sand-blast to the restoration of worn-out files is becoming very general in Europe. A file of moderate dimensions requires only three or four minutes for renovating. The process can be repeated many times before the files need to be recut, and the sand-blast sharpening lasts six times as long as any other. The sand should be very fine and driven with great velocity.—*La Gaceta Industrial.* C.

Early Snow.—"The oldest inhabitant" of Vienna does not remember so heavy a snow-fall in the early part of November, as that of the present season. The squall began soon after midnight and continued through the whole day of Nov. 3. By 11 A. M. it was almost impossible to move in the streets. In the public gardens, at the Prater and on the Ring, the havoc was fearful, and many of the beautiful trees of the Ringstrasse were seriously injured. Many of the cast iron telegraph poles were thrown down, and one of them killed a passer-by. Telegraph wires were broken, and on some of the lines communication was interrupted for several days.—*Les Mondes.* C.

Electro-Chemical Action Under Pressure.—In a series of about 50 experiments, each of which continued for several hours, and during which pressures of 100, 200, 300, etc., atmospheres were maintained, A. Bouvet found the following laws: 1. The decomposition of water by a current is independent of its pressure. 2. The quantity of electricity necessary to decompose a given weight of water is sensibly the same, whatever may be the pressure. The laws are in perfect accordance with the mechanical theory of heat, the work being represented by the formula:

$$T = P\,V \int \frac{dv}{v} = P\,V \text{ log. hyp. } \frac{V_1}{V}$$

T, work; V_1, final volume; V, volume of compressed gas; P, pressure. Bouvet claims to have pointed out the principles of Cailletet and Pictet, in a memoir addressed to the French Academy Oct. 8, 1877.—*Comptes Rendus.* C.

Registering Electrometer.—The quantities of atmospheric electricity and terrestrial magnetism are so minute that they have hitherto been measured by delicate apparatus and recorded by photography, a process which is very costly and often unsatisfactory. Mascart has invented a mechanical register, to accompany Sir Wm. Thomson's electrometer, which gives admirable results. It can be connected with various other instruments.—*La Nature.* C.

Gypsum in Cement.—During the past decade, the use of Gypsum for the improvement of ill-burnt Portland cement has attracted some attention. F. Schott gives the following results of experiments :

		Tenacity, after 7 days	
	Weight.	Air.	Water.
Pure cement,	100	10·5	8
“ “ with 1 p. ct. unburnt gypsum,	115	14·0	—
“ “ “ 3 “ “ “	120	18·0	10
“ “ “ 1 “ dead burnt “	112	11·0	—
“ “ “ 3 “ “ “	113	12·5	—
“ “ “ 3 parts sand,	—	8·0	6
“ “ “ 3 “ “ &3 p.ct.u.b.gyp.	—	13·0	7

—*Dingler's Journal.* C.

Spectral Investigations.—E. Wiedemann has studied the spectrum of mixed gases, especially in Geissler tubes, with a view to extending the theory of spectral lines and bands. The rotary and oscillatory movements of the atoms and molecules appear to produce periodical vibrations in the surrounding luminiferous æther, and the harmonic arrangements which have been pointed out in the lines of many of the chemical elements are probably due to those vibrations. The transfer of electricity from particle to particle differs in different substances, so that only certain portions are illumined by the mere passage of the spark. This fact, together with some phenomena of fluorescence, serves to prove that the oscillations of the æthereal envelopes can be exerted without increasing the living power of all the particles, as would be necessary according to the Kinetic theory of gases. In order to test this hypothesis, Wiedemann has begun a series of experiments in which the temperatures of the discharges in Geissler tubes will be determined under various circumstances.—*Ann. der Phys. u. Chem.* C.

Swiss Coal.—Switzerland has hitherto been obliged to import all its coal, but a bed has been lately discovered at Sonnenberg, near Luzerne. It is in the oldest tertiary, and contains two veins of about 3000 metres (1·864 miles) in length. It is of excellent quality, and the beds are thick enough to be favorably worked, averaging about 1 metre (39·37 inches). Four galleries have been opened already, and a fifth is under way.—*Les Mondes.* C.

The Earth Speaks.—In June last, Palmieri first observed that the seismograph, with the aid of a transmitting microphone and a receiving telephone, enables the ear to hear the vibrations of the ground. Rossi subsequently experimented with a more delicate apparatus, and at each manifestation of the volcanic eruption he heard the same sounds in the agitated soil. The two professors have repeated their observations at Pozzuoli and Solfatara, with the same results.—*Roma.* C.

Ytterbium.—In continuing his analysis of *gadolinite*, Marignac finds that Erbium contains two distinct oxides. One is of a pure rose color, with a very characteristic absorption-spectrum; the other is white, its salts are colorless, its nitrate is decomposed by heat without coloration, its solutions show no absorption rays, it is not easily attacked by acids, and its equivalent is relatively high. He proposes that the first shall retain the name of Erbium, and the latter shall be called Ytterbium.—*Comptes Rendus.* C.

Electrization of Plants.—On July 30, 1877, M. Celi planted three kernels of maize under each of two bell-glasses. The weight of the kernels, the kind of earth, and the quantity of water supplied daily, were equalized as nearly as possible. On Aug. 1, the kernels sprouted. During two days the growth was nearly the same, under both glasses. On the third day the plants in electrized air began to develop more rapidly than the other. On Aug. 10 the following measurements were taken, from the base of the stalk to the extremity of the upper leaves:

Plants in electrized air, . .	17 cm.	(6·69 in.)
" " ordinary " . .	8 "	(3·15 in.)

—*Comptes Rendus.* C.

Decipium.—In continuing his researches upon samarskite, Delafontaine reports the discovery of a new metal which he calls *decipium* (from *decipiens*, deceitful). This metal possesses many of the properties which are common to cerite and gadolinite. He believes its color to be white, although he has not yet separated it sufficiently from didymium to be positive on this point. Its salts are colorless by themselves; the acetate crystallizes very readily and appears to be less soluble than that of didymium but more so than that of terbium.—*Comptes Rendus.* C.

American Cartridges.—The Americans excel all other nations in the quality of their cartridges. The superiority is due in part to the alloys which they use, in part to the machinery, and in part to the skill of the workmen. The Russian, French, German and Turkish Governments have sent official experts to study the American methods and intelligent mechanics to work in the American factories as journeymen. But the result has not been satisfactory; although using the same processes, the cartridges which they have made are of inferior quality.—*La Gaceta Industrial.*

Bridge over the Douro.—The *Maria-Pia* bridge, built by Eiffel, of Paris, has a central bay of 160 meters (174·98 yards) span, the longest yet built for any but suspension bridges. The other chief spans are the Britannia bridge, 140 meters; bridge of Kuilembourg, 150 m.; St. Louis bridge, 158·5 m. Work was begun in Jan., 1876, and finished Oct. 31, 1877. The weight of iron is 1450 tonnes (3,196,700 lbs.), of which 750 tonnes are for the arch and 700 for the roadway and piles. The amount of masonry is 4000 cubic metres (5232·086 cubic yards).—*La Nature.* C.

Electricity of Chemical Processes.—F. Braun finds that the percentage of potential energy convertible into mechanical work, varies inversely with the electric tension; a sudden change in the density of free electricity must be accompanied by a development of heat even if it is not followed by any change of relative distribution; if induction-currents in a spiral excite a maximum of free electricity, half of the work is converted into heat; in currents of small intensity, if a new current is added, a greater development of heat and a less degree of polarization arise when the new current is in the same direction as the original current than when the directions are opposite.—*Ann. der Phys. u. Chem.* C.

Chanoit Filter.—A metallic reservoir is supplied by a pipe entering at the bottom. The water is forced by the pressure of a hydrant, or of a head, upward through the filtering bed, compressing the air before it, and thus becoming thoroughly aerated. The filter can be readily cleaned by opening a discharging cock in the bottom. Faucets for drawing the filtered water, or for conveying it to other rooms, are inserted above the bed.—*La Nature.* C.

Greek Bread.—The ancient Greeks used covered terra-cotta utensils, called *cribanoi,* which were pierced with holes in their circumference, and which were the prototypes of the modern "Dutch ovens." After the dough was put in they were surrounded by burning coals, and the heat, penetrating by the holes, gave a more uniform temperature than an ordinary oven. After the reign of Pericles, Athens became renowned for the skill of its bakers and its cooks. They made twenty or more kinds of bread, some of which were very white and of excellent flavor. Plato reports that, a century before his time, a Sicilian baker, named Thearion, had made great improvements in his art. The Cappadocians made a very delicate bread, like Vienna rolls, by adding to the wheat flour a little milk, oil and salt.—*La Nature.* C.

Werdermann's Electric Light.—The principle is much like Reynier's. A slender carbon moves in a metallic tube, which serves both as cylinder and as conductor of the current. A collar on the lower portion connects it by cords to a counterpoise, which tends to raise the carbon and keep it lightly pressed against a carbon disc, two inches in diameter, kept in a fixed position by a vertical support, and connected with the negative pole. The incandescence is limited to the portion of the positive margin (about $\frac{3}{4}$ inch) between the metallic tube and the negative disc. A gramme machine, driven by an engine of two horse-power gave the following results: 1. When the current was distributed between two lamps, it gave a light of 360 candles, white and perfectly steady. 2. When divided between ten lamps, each focus represented about 40 candles, and the total resistance of the circuit was only 0·037 ohms. 3. The disc, on account of its great mass, does not burn or undergo any change. The crayons consume less than 3 inches per hour for large lamps. All the lamps can be lighted or extinguished either at once or successively.—*Comptes Rendus.* C.

Electrophone.—C. Ader uses a sort of drum, having on one side a diaphragm of parchment paper, about 15 cm. (5·91 in.) in diameter, in the centre of which are circularly arranged six bits of tinned iron, 1 cm. (·374 in.) long, and 2 mm. (·079 in.) wide. Upon these act six microscopic horse-shoe electro-magnets, which are connected and set in action by a carbon-speaking microphone. A Leclanché pile of three elements transmits words and music so that conversation can be heard 5 meters (16·4 ft.) from the instrument. The energetic efforts are due to the minuteness of the electro-magnets, which can be magnetized and demagnetized much more rapidly than in other systems.—*Comptes Rendus.* C.

Magnetism of Loadstone and of Steel.—Dr. A. L. Holz has investigated the comparative influences of equal amounts of magnetism upon the loadstone and upon glass-hardened steel. He has reached some novel conclusions, among which are the following: 1. The maximum of permanent magnetism in the loadstone, for equal volumes, is about the same as that in the hard steel. 2. The specific magnetism of the loadstone is the greatest of all magnetic bodies yet investigated. 3. The permanent magnetism of the loadstone is sooner reached than that of steel. 4. The quantity of temporary magnetism which disappears, after the magnetizing force is removed, is less in the loadstone than in steel.—*Ann. der Phys. u. Chem.* C.

Spontaneous Combustion.—E. Bing, of Riga, has experimented with different materials; wadding, raw flax, hemp, the waste from silk, wool and cotton spinning as well as sponge, and finally wood dust as found in any cabinet-maker's shop. They were saturated with various fluids, viz., oils, fresh and in a gummy state; turpentine, petroleum, various varnishes, etc.

All the fibrous materials took fire when saturated with any of these oils or with mixtures of the same. Sponge and wood dust, on the contrary, proved to be entirely harmless.

Combustion ensued most rapidly with 17 g. of wadding and 67 g. of a strong oil varnish, in 34 minutes; while 200 g. of washed cotton waste, of which a portion was saturated with 750 g. of strong oil varnish and the remainder wrapped about it, required almost 14 hours. These materials were placed in a well-sheltered spot and subjected to a heat of from 18° to 40° (C.)

Silk did not flame up, but slowly charred. Small quantities seem to take fire sooner than large.—*Wochenschrift des Ver. deutsch. Ing.* P.

A THIRD VERIFICATION OF PREDICTION.

Editors JOURNAL FRANKLIN INSTITUTE:

Gentlemen:—Th. von Oppolzer (*Comptes Rendus*, Jan. 6, 1879) gives elements, deduced from eight supposed planetary sun-spots, which represent another of my harmonic positions:

	Dist.	Time.
Von Oppolzer, . . .	·123	15·8 days.
Chase, predicted, . .	·120	15·1 "

This leaves only one still "missing link" in the principal harmonic series, between the nearest fixed stars and the sun. There are many secondary or possible asteroidal positions, between Mercury and the Sun, one of which has been filled already by Mouchez's second Watson orbit.

Yours truly,

PLINY E. CHASE.

HAVERFORD COLLEGE,
February 10*th*, 1879.

Book Notices.

THE RELATIVE PROPORTIONS OF THE STEAM ENGINE. By WM. D. Marks, Whitney Professor of Dynamical Engineering, University of Pennsylvania. Small 8vo, pp. 161. J. B. Lippincott & Co., Philadelphia, 1879.

This is a course of lectures on the steam engine, delivered to the students of dynamical engineering in the University of Pennsylvania, in which the author has reduced all the required dimensions to functions of the steam pressures, length and number of strokes and horse-power.

While accepting the great value of the writings of Zenner, Poncelet, Huss, Reuleaux and others upon the subject, covering thoroughly the principle of the steam engine, and treating fully some of its members, the author felt that a practical method of determining the proper relative proportion of all parts of the steam engine, was still a desideratum in the English literature of the subject. He has drawn largely from standard writers upon points already well established, while he has studied fully those which have not received the attention they deserve.

The book is clearly printed on tinted paper, and well indexed.

We are informed that this work has been adopted as a text-book in the Sheffield Scientific School, Lehigh University and the University of California.

Franklin Institute.

HALL OF THE INSTITUTE, Feb. 19th, 1879.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. W. P. Tatham, in the chair.

There were present 157 members and 47 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers and reported that at the last meeting 3 persons were elected members of the Institute, and that there was a vacancy in the Board caused by the election of Mr. Tatham to the Presidency.

The Committee on the Library reported the following donations:

First to Fifth Annual Reports of the Water Board of the City of Lowell to the City Council, January 1, 1874, to January 1, 1878.
From the Lowell Water Board.

Eighth, Thirteenth, Fourteenth and Fifteenth Reports of the Board and First and Second Reports of the Department of Public Works of Chicago. Chicago, 1869, 1874, 1875—1878.
From D. S. Mead, Secretary.

United States Geological Exploration of the Fortieth Parallel. C. King, Geol. in Charge. Vol. 1. Systematic Geology. Washington, 1878.
From the Chief of Engineers.

Steel plate Portrait of John Sartain. From C. Lartenbacker.

Specifications and Drawings of Patents for August, 1878.
From the Commissioner of Patents, Washington.

Fourteenth to Nineteenth and Twenty-first Annual Reports of the Board of Trustees of the Water Works of Cleveland, 1869—1874 and 1876.
From the Board.

Annual Report of the Comptroller of the Currency to Third Session of Forty-fifth Congress of the United States. Dec. 2, 1878.
From J. J. Knox, Comptroller, Washington.

Transactions of the Royal Irish Academy. Vol. 26, Science, Parts 6—16, and Vol. 27, Polite Literature and Antiquities, Part 1; Proceedings, Vol. 1, No. 12; Vol. 2, No. 7, and Vol. 3, No. 1.
From the Royal Irish Academy, Dublin.

Annual Reports of the Light House Board to the Secretary of the Treasury, for 1867 and 1869.
From the Treasury Department, through Hon. Chas. O'Neill.

Pennsylvania Archives. Second Series. Charter, 1682.
From the Historical Society of Pennsylvania, Philadelphia.

Polar Colonization. A Memorial to Congress, etc.
From H. W. Howgate, U. S. A.

Researches in Telephony. By Prof. Dolbear. 1878.
From the Author.

Conférence faite au palais du Trocadéro le 7 Aout, 1878. Par M. Malezieux. Paris, 1878. From the Author.

Floral Guide. By J. Vick. Rochester, N. Y., 1878.
From the Author.

Experimental Trials of the Power required to Drive certain Ring Spindles, made by J. B. Francis, Lowell, Mass. From the Author.

Drift from York Harbour, Me. By George Houghton, N. Y.
From the Author.

Reports of Permanent Committee of First International Meteorological Congress at Vienna. London, 1878.
From the Meteorological Committee of Royal Society.

Aeneidea; or Critical, Exegetical and Aesthetical Remarks on the Aeneis. By J. Henry. Vol. 1 (3 parts) and Vol. 2 (1 part). Duplin, 1878. From the Royal Irish Academy.

Geological Survey of Missouri. Reports of State Geologists for 1855—1876. With two Atlases.
From C. P. Williams, Acting Geologist, Philadelphia.

Reports of the Auditor-General of Pennsylvania on the Finances of the State for 1875—1877. From the Auditor-General.

Report of Chief of Ordnance for 1878. Washington, 1879.
From the Chief of Ordnance Bureau.

United States Geological Explorations of Fortieth Parallel. Vol. 5. Botany. C. King, Geologist in Charge.
From the Chief of Engineers.

Brevet d'Invention. Law of 1791. Vols. 48 to 55, 1843–45. Vols. 81 to 93, 1853–63. With Index to Vols. 41—93.—Old Series Law of 1844. Vols. 16 to 47, 1853–64. Vols. 56 to 80, 1864–73 and 85 to 88. With Indexes for Vols. 1—79, in 4 vols.—New Series. Vols. 9 to 13, 1876–78. In 93 vols.

Catalogues des Brevets delivrés du 1er Janvier, 1828, au 31 Dec., 1877. In 36 vols.
From the Minister of Agriculture and Commerce of the Republic of France, Versailles.

Cartes des Voies et Communications de la France. En 6 feuilles.

Cartes des Voies et Communications. En 2 feuilles.

Cartes de la Navigation Interieur.

Carte du Tonnage des Routes Nationales.

Carte du Tonnage de la Navigations.
From the Minister of Public Works of the Republic of France, Versailles.

Mr. John Richards read the paper announced for the evening on Measuring and Gauging Implements.* The subject of the paper was exemplified by a measuring machine of six inches capacity, and believed by the author to be as nearly perfect as any ever built. Also the transfer measuring machine and a large number of gauging and calipering implements.

In the discussion which followed the reading of this paper, Mr. J. W. Nystrom stated the first English standard yard was a brass bar called the parliamentary standard, made by Mr. Bird in the year 1758. About two years later, or in the year 1760, the same maker made another brass bar yard, which was considered the English standard, but not legalized by act of Parliament until the year 1825, when it was termed the imperial standard. Its correct length should be at a temperature of 62° Fahrenheit. Sir George Shuckburgh, who took great interest in correct measures of length, compared the two Bird's standard yards, and found them to differ about $\frac{2}{10000}$ths part of an inch.

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* See page 172.

In the latter part of the last century, Mr. Troughton, of London, was celebrated for having the most correct engines for dividing lengths, and he was, therefore, engaged by Sir Shuckburgh to make a standard yard divided into thirty-six inches with subdivisions, which yard was adopted by scientific men as the highest authority, not so much for its correct length, but principally for its accurate divisions.

Mr. Troughton was then known to have the most delicate apparatuses for comparing standard lengths, and was thereupon engaged by our government to make a standard measure of length for the United States, equal to that of the English. Thus he made a brass scale eighty-two (82) inches long, which was deposited in the Office of Weights and Measures at Washington and adopted by the United States Coast Survey. Its correct length should be at 62° Fahrenheit.

The United States standard yard was taken from this scale, between the 27th and 63d inches. (See Report on Weights and Measures, by A. D. Bache, 1857.)

It has since been found that the standard yard, so obtained, was 0·00005803 longer than the English imperial standard yard. This difference was no doubt due to incorrectness of the divisions on the original scale, or derived from insufficiently delicate appliances for reading off the measure from the English standard.

It cannot be expected that the divisions on the English scale could be very correct, from want of knowledge in those days to make a correct screw, which is yet a difficult problem, even with our advanced knowledge of mechanic arts.

It was thus originally intended to have the English and American standards of length alike, and we ought not to acknowledge any difference. The Smithsonian Institution published tables in the year 1859, comparing the length of the English and American foot measures, which makes the American yard $\frac{2}{1000}$th parts of an inch longer than the Imperial standard yard, or a difference of four (4) inches per mile.

The United States Coast Survey has now made the American standard yard the same length as the Imperial standard yard.

Mr. P. H. Dudley exhibited and described his system of synchronizing clocks for different longitudes from a central station, and also his method of constructing diagrams, illustrating graphically the lowest rates at which railroads can carry freight.*

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*See page 196.

Prof. W. D. Marks described the working of his compound compass for describing arcs of circles up to an infinite radius, all of the conic sections for curves of higher degrees, it being an adaptation of Purcelle's parallel motion; also a linkage of his invention for describing epi- and hypo-cycloids.

The Secretary presented a large astronomical transit and clock, being parts of a set of instruments built by Messrs. Heller & Brightly for the State University of Oregon.

Deacon's waste-water meter, which makes a diagram of the comparative quantity of water passing at any period, by means of which the wastage from leaks, open faucets, etc., in any water-supply system may be detected; Ball's device for making change with coins, consisting of a series of tubes of proper sizes to hold coins of the various denominations, and having at the bottom of each, a slide operated by a lever in such a manner, that when the lever is pressed down, one piece of coin is dropped into a receptacle below. When the coins necessary to make the sum required are all deposited, a slide in the bottom of the receptacle is pushed back by the ends of the fingers in such a manner as to bring the palm of the hand under the opening to receive the coins: Also a new metallic shingle, made of sheet iron cut to a point at one end, and having corrugations which fit into each other and prevent the wind from driving the water under the shingles when laid.

The resolutions of the Board of Managers and of the Committee on Sciences and the Arts relative to the award of medals were called up, when, on motion, the whole subject was laid upon the table.

On motion, the Institute went into the election of one Manager, to serve two years, to fill the vacancy reported from the Board, and the Chair announced that nominations were in order, whereupon Messrs. Henry Cartwright and John J. Weaver were placed in nomination. The Chair appointed Messrs. G. M. Eldridge and C. Chabot, tellers to conduct the election, and after all had voted who wished, the Tellers reported that Mr. Cartwright had received 40 votes and Mr. Weaver 8 votes, whereupon the Chair declared Mr. Cartwright elected to fill the vacancy specified.

The President announced the following standing committees for the current year:

On the Library.—Chas. Bullock, Wm. A. Ingham, Dr. Isaac Norris, Jr., Rob't Briggs, J. B. Knight, Henry Pemberton, J. Sellers Bancroft, J. E. Mitchell, Jos. M. Wilson, Fred. Graff.

On Minerals.—Dr. F. A. Genth, Theo. D. Rand, Clarence Bement, Persifor Frazer, Jr., Dr. W. H. Wahl, E. J. Houston, Otto Luthy, E. F. Moody, Dr. G. A. Kœnig, H. Pemberton, Jr.

On Models.—C. Chabot, H. L. Butler, Edward Brown, M. L. Orum, J. Gœhring, L. L. Cheney, J. J. Weaver, S. Lloyd Wiegand, A. G. Busby, N. H. Edgerton.

On Arts and Manufactures.—J. J. Weaver, Geo. V. Cresson, Hector Orr, Coleman Sellers, Jr., W. B. LeVan, Wm. Helme, J. S. Bancroft, Alfred Mellor, Cyrus Chambers, Jr., Geo. Burnham.

On Meteorology.—Pliny E. Chase, Hector Orr, Dr. Isaac Norris, Jr., John Wise, Jas. A. Kirkpatrick, Alex. Purves, Dr. W. H. Wahl, F. M. M. Beale, H. Carville Lewis.

On Meetings.—H. Cartwright, Washington Jones, J. B. Knight, C. S. Close, L. M. Haupt, W. L. DuBois, W. H. Thorne, Cyrus Chambers, Jr., J. J. Weaver.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*

JOURNAL

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CONCERNING $\frac{T_1 - T_0}{T_1}$; OR, THE LIMIT OF EFFICIENCY OF HEAT ENGINES.

BY J. F. KLEIN, D. E.,

Insructor in Dynamical Engineering, Sheffield Scientific School.

(Continued from vol. lvii, page 160.)

The important propositions that a heat engine cannot perform work by the expansion and contraction of its volume without rejection of heat, and that the maximum efficiency of all heat engines is represented by the proper fraction $\frac{T_1 - T_0}{T_1}$, are either of them sufficient to completely overthrow the thermodynamic fallacies mentioned at the beginning of this paper. We will not, however, thus summarily dispose of the special arguments advanced in support of the fallacies, but will give them the careful examination which the importance of the principles they attack, rather than their own inherent force, seems to demand. These special arguments are all contained in the paper of Prof. R. H. Thurston, and are as follows:

I. That the influence which the nature of the working substance might have on the theoretical efficiency of an engine has been neglected by accepted authorities in thermodynamics, having been passed over by them as unimportant.

II. That the maximum efficiency of the ordinary type of steam engine depends upon the specific heat of its working substance, and can be greater than $\frac{T_1-T_0}{T_1}$.

III. That air and gas engines have been designed and built, whose theoretical efficiency was unity, all unutilized heat being restored to the working substance by means of a mass of metal called a "Regenerator."

IV. That it is theoretically posrible to have a "New Type of Steam Engine" which will perform work without rejecting heat, by returning the working substance to the boiler in a peculiar manner.*

Now what are the facts as regards the first of these statements? In the papers and treatises of Clausius, W. Thomson, Rankine and Hirn may be found a demonstration concerning the efficiency of engines in which the influence of the nature of the working substance has been taken into account. Rankine in particular has given special attention to this very matter by taking into consideration mixtures of the working substance in which "the properties of the ingredients are constant, as in the aggregate of chemically distinct substances, or variable as in the aggregate of a liquid and vapor."† The demonstration given by Clausius and W. Thomson of Carnot's principle—that a reversible engine receiving and discharging heat only at its upper and lower limits of temperature respectively, is *at least* as efficient as *any other* engine having the same source and refrigerator—was intended te cover and does cover the three cases, in which the engines compared differ either as to reversibility, as to the working substance employed, or in both these respects. Prof. Thurston should therefore have discussed this simple and famous demonstration and show wherein it was faulty, if he wished to establish his proposition, that the maximum efficiency of an engine does depend upon the nature of the substance employed.

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*The "New Type of Steam Engine" was invented by Prof. R. H. Thurston in 1858—1859. We understand that Mr. Chas. E. Emery subsequently and independently re-invented this engine, and claimed that it was "based on modern thermodynamic developments"!!

† See *Phil. Trans.*, 1854, vol. 144, p. 144.

There is a *very* concise statement to the same effect in Rankine's "Steam Engine," p. 308.

See also text-books on heat, by McCulloch, Cotterill and Balfour Stewart.

Instead of this we find the demonstration given by Clausius and Thomson completely ignored and an unsuccessful attempt made to show that reversibility is "the perfect test of the perfect engine."

II. *That the maximum efficiency of the ordinary* type of steam engine depends upon the specific heat of its working substance, and can be greater than* $\frac{T_1 - T_0}{T_1}$.

Before stating and examining the reasons advanced in support of this proposition we will first call attention to the terms latent heat and real specific heat, and will then call attention to the difference of opinion concerning the variability of the latter which existed between Rankine and Clausius. It will then be readily seen that Prof. Thurston has chosen a disputed point as the basis of his reasonings, and that his mistaken idea as to what constitutes the total actual heat of a body has first led him into confusion and error, and then to conclusions concerning the efficiency of engines entirely at variance with those held by all accepted authority, including both Rankine and Clausius.

It should be remembered throughout that *Heat* is a kind of *actual* or kinetic energy, consisting in the invisible *motions* of the particles of a body, and that *Heat* is not potential energy, for its ability to perform work depends only on the *heat-motions* of the particles, and not on their relative *positions*. Suppose now that one pound of a body receives heat under such conditions that its volume and temperature both increase; then of the total heat received a part will continue to exist as heat by increasing the heat-motion already present within the body, whilst the remainder *disappears* as *heat* by performing the external and internal work necessary to effect the change of volume. The internal work consists in overcoming the molecular resistances to separation, or change of arrangement, of the particles, and is often very much greater than the external work, which has only to overcome the external pressures resisting the change of volume. For water, when it is being evaporated under constant pressure the ratio of the two is often very great, the internal work being at least 10 to 15 times as great as the exterior work (for the pressures ordinarily occurring in engines). In some steam tables the interior work is given under the heading "internal latent heat," the exterior work being given under "external latent heat." The sum of these two quantities is usually called the "latent heat of evaporation." This objectionble term, "latent heat,"* has come down to us from a time when heat was supposed to be a substance and consequently indestructible, and although we now know that heat, as such, can be put out of existence by transformation into other forms of energy which do not affect the thermometer, still the term remains, and continues to lead many to believe that the heat which has disappeared in doing work still lurks concealed somewhere in the working substance as *heat;* this is less often the case when external work only is considered, for the equivalent of the disappeared heat is then seen in visible external work; but when the internal work done in separating the molecules and changing their arrangement is under consideration the beginner is apt to think that this kind of work "don't count," and that the heat which has been expended in accomplishing it still exists in the body as heat, instead of recognizing that in this case also it has *disappeared* by being transformed into another kind of energy—that of position—which does not affect the thermometer.

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*According to Prof. Thurston there are at least two types of heat engines: those which reject heat and those which do not; the ordinary steam engine belonging to the first type.

We have thus far supposed that a change of volume accompanies the change of temperature when heat is furnished to a body, but will now suppose the body to be kept at constant volume during reception of heat. The external work will then become equal to zero, and the internal work will be diminished; consequently a greater proportion of the heat furnished will go to increase the actual sensible heat of the body. If the body is one of the more permanent and perfect gases, the interior work will become approximately equal to zero, and all the heat furnished may then be said to be employed in increasing the temperature or actual heat of the body. If, however. the body be either a solid, liquid, or saturated vapor, there is nothing in theory or experiment which would justify us in asserting that the interior work is equal to zero; for forces of cohesion may have to be overcome, and changes of arrangement of the molecules and their components may take place, which require work and cause a portion of heat to disappear.

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* Now that "latent heat" has become a part of the popular vocabulary, it will be difficult to get rid of it; no error can arise in its use, however, if understood as defined by Maxwell: "Latent heat is the quantity of heat which must be communicated to a body in a given state in order to convert it into another state without changing its temperature."

If the body is of unit weight, and receives heat sufficient to raise its temperature one degree, the total amount of heat received is called its *apparent* specific heat; if from this be subtracted all the heat which is expended in performing interior and exterior work, the remainder is called the *real* specific heat, because it alone measures the actual heat of the body. We will represent the apparent specific heat for the general case by C and for constant volume by C_v. The real specific heat we will represent by K. Experiment shows that for a given state of aggregation—solid, liquid or gaseous—C_v is the minimum value of C, also that C_v is greatest for the liquid and least for the gaseous state. Only for highly superheated vapors like air do experiments indicate that C_v is nearly equal to K.

The following proposition is due to Clausius and is a result of his mathematical investigations on the effective force of heat and on disgregation (a quantity representing the arrangement of the particles of a body).

"The quantity of heat actually present in a body depends only upon its temperature, and not upon the arrangement of its constituent particles." In other words, the real specific heat of a body is the same for all temperatures, and for all states of aggregation—solid, liquid or gaseous, and we may therefore write

$$H = K\,T = C_v\,T$$

$$\text{and} \qquad \frac{H_1 - H_0}{H_1} = \frac{T_1 - T_0}{T_1} \qquad (5)$$

where H is the quantity of actual heat present in the body at the absolute temperature, $T = 461° + t^0$ F and C_v the apparent specific heat under constant volume when the body is in the form of a vapor highly superheated.

But Rankine had taken an opposite view of this matter, saying, "The real specific heat of each substance is constant at all densities as long as the substance retains the same condition—solid, liquid or gaseous; but a change of real specific heat, sometimes considerable, often accompanies the change between any two of these conditions."

Clausius showed that the reasons given by Rankine in support of this view were decidedly insufficient, whereupon Rankine replies: "I admit that it is difficult to conceive how the same substance can alter its real specific heat in changing its state of aggregation. But it is also difficult to conceive how the elevation of temperature of liquid water, for example, can be accompanied by internal work to an amount sufficient to account for the excess of the specific heat of liquid water at constant volume above that of steam and above that of ice, those three quantities being nearly as follows:

Specific heat at constant volume of		ice, about	0·50
"	"	liquid water,	1·00
"	"	steam,	0·37."

Rankine, after suggesting that both difficulties are diminished if not removed by supposing the composition of the molecule to change with the state of aggregation (an atom of ice or steam, for example, being composed of two atoms of liquid water), continues thus:

"I do not, however, propose that supposition as more than a conjecture; and for the present I am content to regard as certain merely the fact that the *minimum* specific heat of the same substance in different states of aggregation is in many cases different, leaving the relation between that minimum specific heat and the real specific heat to be ascertained by further investigation."*

Were we to follow Rankine, we would write

$$H_1 = K_1\, T_1 \qquad\qquad H_0 = K_0\, T_0$$

$$\text{and} \quad \frac{H_1 - H_0}{H_1} = \frac{K_1 T_1 - K_0 T_0}{K_1 T_1} = \frac{T_1 - \frac{K_0}{K_1}\, T_0}{T_1} \qquad (6)$$

where H_1, H_0 and K_1, K_0 represent the total actual heat and the average real specific heat corresponding to the physical states of the body when at the absolute temperatures T_1, T_0, respectively.

At this point it must not be forgotten that the efficiency of engines, represented by

$$\frac{W_1}{JQ_1} = \frac{Q_1 - Q_0}{Q_1} = \frac{T_1 - T_0}{T_1} \qquad (7)$$

does not at all depend upon the correctness of either of the foregoing views, having been established by means of the two principles: "Heat and work are mechanically equivalent," and "Heat cannot, of itself, pass from a colder to a warmer body."

We will now give, and as often as brevity will allow in the Professors's own words, the reasonings which lead to the conclusion that the efficiency of a steam engine should be greater than $\frac{T_1 - T_0}{T_1}$.

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* See *Phil. Mag.*, vol. 30, 1865, p. 410; also "Steam Engine," p. 307.

"In any fluid, no change occurring in its capacity for heat with change of temperature, the quantity of heat present in the mass is proportional to its absolute temperature."

For perfect gases, therefore,

$$H_1 : H_0 = T_1 : T_0 \text{ and } \frac{H_1 - H_0}{H_1} = \frac{T_1 - T_0}{T_1}$$

"The same is true approximately, if not absolutely, of superheated and of dry steam," * * * * and of water unmixed with vapor; for these, therefore,
$$\frac{H_1 - H_0}{H_1} \overset{>}{=} \frac{T_1 - T_0}{T_1}$$

But when steam expands and condenses it changes its physical state and the specific heat of the mixture then varies as the proportions of the liquid and vapor which it contains vary.

"*But this mixture of liquids and vapor contains, usually, vastly less heat than an equal weight of steam at the same temperature.*"

Therefore, for steam

$$\frac{H_1 - H_0}{H_1} > \frac{T_1 - T_0}{T_1}.$$

"Hence, the steam engine *should be* more economical than the air or gas engine working between the same limits of temperature. That it is not, can only be due to the cause of loss already adverted to as peculiar to the steam engine." [The loss referred to is that due to the condensation and re-evaporation which takes place in the steam cylinder.]

This demonstration evidently contains the two following assumptions:

(1.) That the real specific heat of steam varies with its state of aggregation, and consequently its total actual heat is not always proportional to the absolute temperature.

(2.) That $\frac{H_1 - H_0}{H_1}$ may represent the theoretical efficiency of an engine without being equal to $\frac{T_1 - T_0}{T_1}$.

We do not see how it is possible to escape the conclusion that the portion of the demonstration which we have italicized contains a third assumption:

(3.) That the "latent heat of evaporation" is identical with the actual heat of the steam, in other words when water is changed into steam of the same temperature, the large amount of heat which *disappears* in doing the work of evaporation continues to exist as actual heat in the steam.

In the mechanical theory of heat this last assumption is an absurdity, the next is without shadow of proof or authority, while the first directly contradicts the result $\frac{H_1 - H_0}{H_1} > \frac{T_1 - T_0}{T_1}$ which the Professor has managed to deduce from it. The first of the above assumptions it will be noticed is identical with that already ascribed to Rankine and and expressed by

$$\frac{H_1 - H_0}{H_1} > \frac{T_1 - \frac{K_0}{K_1} T_0}{T_1} \tag{6}$$

If now we assume with Rankine that the real specific heat of steam and water are, at least, approximately equal to their specific heats under constant volume,

$$C'_v = 0{\cdot}37 \text{ and } C''_v = 1{\cdot}00$$

and also let H_1 represent the total actual heat in a pound of steam when at the absolute temperature T_1 and H_0 the total actual heat present in a *mixture* weighing one pound and containing x per cent. of steam and $1 - x$ per cent. of water, we shall have for the mean specific heat

$$K_0 = xC'_v + (1 - x)\, C''_v = 1 - 0{\cdot}63\, x,$$

and for Eq. 6 $\frac{H_1 - H_0}{H_1} = \frac{T_1 - \frac{1 - 0{\cdot}63\, x}{0{\cdot}37} T_0}{T_1}$

When $x = 0{\cdot}50$ *i. e.*, when the mixture is half water and half steam, we have $\frac{H_1 - H_0}{H_1} = \frac{T_1 - 1{\cdot}85\, T_0}{T_1} < \frac{T_1 - T_0}{T_1}$, and since a similar result may be obtained from any other mixture of the water and steam we see that the first assumption made by Prof. Thurston directly contradicts the result which he has deduced from it.

We have already seen that if we accept Clausius' view of the invariability (in the same substance) of the real specific heat that we are led to a result likewise opposed to to that deduced by the Professor, but we must remember that the intelligible and interesting relation

$$\frac{H_1 - H_0}{H_1} = \frac{T_1 - T_0}{T_1} = \frac{Q_1 - Q_0}{Q_1} = \frac{W}{J\, Q_1}$$

which we then obtain between the total actual heat and the efficiency cannot, by any means, be said to have the same validity as the relation

$$\frac{Q_1}{Q_0} = \frac{T_1}{T_0}$$

or

$$\frac{Q_1 - Q_0}{Q_1} = \frac{W}{J\,Q_1} = \frac{T_1 - T_0}{T_1}$$

which depends only on laws deduced from experiment.

We should also remember that the absolute temperatures* T_1, T_0 of our formula can be easily obtained with considerable accuracy from a standard thermometer while the total actual heat cannot be directly measured but must be obtained by calculation, involving hypotheses which though probable cannot yet be regarded as established experimentally. These reasons are sufficient for preferring $\frac{T_1 - T_0}{T_1}$ as an expression for the efficiency of an engine rather than $\frac{H_1 - H_0}{H_1}$ and we accordingly find that Clausius, W. Thomson, Maxwell, Rankine, Hirn, and Zeuner have all avoided introducing the total actual heat into the expression for the efficiency of engines.

Professor Thurston makes no attempt to calculate the efficiency of an engine from the total actual heat of the working substance, he nowhere introduces the real specific heat into his calculations, although the neglect of this consideration has constituted (if we are to believe the Professor) "a serious and hitherto unsurmounted difficulty in the process of calculation of the exact efficiency of the steam engine." We even find that the Professor so far forgets the points made at the beginning of his paper about the influence of a change of physical state on the efficiency of an engine, as to choose for the exponent of the adiabatic curve of *saturated* or *wet* steam a value ($\frac{4}{3}$) belonging to highly *superheated* steam. This occurs in an example in which the Professor works out "the true theoretical economy of a steam engine," the method employed being the well-known one of dividing the heat utilized as work by the total heat expended, or

$$\text{Efficiency} = \frac{W}{J\,Q_1} = \frac{Q_1 - Q_0}{Q_1}$$

the error consists in obtaining too small a value for the rejected heat

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* See note at end of article.

Q_0 by means of an excessive exponent for the curve of expansion. In this example the engine is supposed to work under the following conditions:

Initial absolute pressure of steam = 90 lbs.
Final “ “ “ “ = 2 “
Initial temperature of steam = 320·0° F.
Final “ “ “ = 126·3° F.
Temperature of feed water for boiler = 110·0° F.
Total heat supplied per lb. of steam at 90 lbs. = 1101·5 heat units.
“ “ rejected “ “ “ “ “ 2 lbs. = 1042·5 “ “
“ “ “ “ “ “ water = 16·3 “ “

For the adiabatic curve of expansion of the saturated steam, *i. e.*, for expansion without transmission of heat, Professor Thurston assumes

$$p\,v^{\frac{4}{3}} = const.$$

taking the initial specific volume $v_1 = 4{\cdot}72$ cubic feet, and $p_1 = 144 \times 90$ lbs.

$$144 \times 90 \times \overline{4{\cdot}72}^{\frac{4}{3}} = 102{,}611. = const.$$

$$\text{and, therefore, } v_0 = \frac{102{,}611}{p_0^{\frac{3}{4}}} = 76{\cdot}53 \text{ cubic feet,}$$

which is the volume of the one pound mixture of water and steam when the pressure p_0 at the end of expansion is 2 lbs. Since the volume of the mixture is practically that of the steam, we get for the weight of the latter 0·44 lbs. Then

Heat lost in rejected steam = 1·042 × 0·44 = 463 heat units.
“ “ “ “ water = 16·03 × 0.56 = 9 “ “
Total heat rejected Q_0 = 472 heat units.
“ “ received Q_1 = 1102 “ “
“ “ utilized $Q_1 - Q_0$ = 630 heat units.

The efficiency of the steam engine will then be

$$\frac{Q_1 - Q_0}{Q_1} = \frac{630}{1102} = 0{\cdot}57.$$

“Had the working fluid been a permanent gas the efficiency would have been one-fourth,” *i. e.*,

$$\frac{T_1 - T_0}{T_1} = \frac{461 + 320 - (461 + 126)}{461 + 320} = 0{\cdot}25.$$

"The difference illustrates the superiority of the condensible vapor as a medium for the conversion of work."

Now it is easy to show that this calculation will not stand the simplest and most obvious test, for we have only to calculate the work (or heat utilized) from the indicator diagram of such an engine and we will find that it is vastly less than the equivalent of 630 heat units.

The work done before cutting off is

$$p_1 v_1 = 144 \times 90 \times 4{\cdot}72 = 772 \times (79.2 \text{ heat units}).$$

The work of expansion when the curve is represented by $p\,v^{k} = p_1 v_1^{\frac{4}{3}} =$ constant, is

$$\frac{p_1\ v_1}{k-1}\left[1-\left(\frac{p_0}{p_1}\right)^{\frac{k-1}{k}}\right] = 772 \times (145{\cdot}9 \text{ heat units}).$$

The work done in overcoming back pressure is

$$p_0\ v_0 = 144 \times 2 \times 76{\cdot}5 = 772 \times (28{\cdot}5 \text{ heat units}).$$

Effective work $= 772 \times (79{\cdot}2 + 145{\cdot}9 - 28{\cdot}5) = 772 \times (196{\cdot}6$ heat units) or less than one-third of the result (630) obtained by Professor Thurston.

These exceedingly discordant results are due to assuming an exponent $\frac{4}{3}$ which is much too large for the adiabatic expansion of steam initially dry, consequently neither of the answers obtained is correct because the erroneous exponent enters into each of the methods employed. Perfectly accordant results are of course not to be expected from empirical formulæ, but a *very much* closer approximation than that obtained may be reasonably expected. The efficiency as determined from the indicator diagram by means of the erroneous exponent $\frac{4}{3}$, will be

$$\frac{196{\cdot}6}{1102} = 0{\cdot}18 < \frac{T_1 - T_0}{T_1} = 0{\cdot}25,$$

so that the Professor's data again lead to results directly contradicting those which he has deduced from them.

Before calculating the work of the above engine by means of the correct exponent of for the adiabatic expansion of steam, we will give the table containing the values of these exponents for various initial and final pressures. This table was calculated by Zeuner by means of Regnault's experiments, and a formula for the adiabatic curve of steam deduced from the fundamental equations of heat. It will be noticed that the values of the table agree very well with the mean value 1·135 assumed by Zeuner for steam initially dry. Using this exponent

Values of exponent k when steam is dry saturated at beginning of expansion:

Initial pressure in atmospheres	Final pressure in atmospheres.			
	0·5	1	2	4
8	1·1321	1·1360	1·1396	1·1431
4	1·1315	1·1354	1·1399	
2	1·1304	1·1344		
1	1·1299			

we have $p_1 v_1^{1.135} = p_0 v_0^{1.135} =$ constant,

$$\text{and } v_0 = v_1 \left(\frac{p_1}{p_0}\right)^{\frac{1}{1.135}} = 4{\cdot}82\,(45)^{\frac{1}{1.135}} = 138 \text{ cu. ft.}$$

weight of uncondensed steam = 138 × 0·0058 = 0·80 lb., consequently heat rejected per pound of mixture equals 1042 × 0·8 + 16·3 × 0·2 = 837 heat units; and since heat supplied per pound of steam = 1101 heat units, the heat utilized will be 1101 − 837 = 264 heat units.

We will now check this result by calculating the utilized heat from the indicator diagram of the engine; then, as before, the effective work will equal

$$p_1 v_1 + \frac{p_1 v_1}{k-1}\left[1 - \left(\frac{p_0}{p_1}\right)^{\frac{k-1}{k}}\right] - p_0 v_0$$

or 62500 + 168600 — 39700 = 772 (248 heat units),

$$\text{and the efficiency } = \frac{248}{1101} = 0.225 < \frac{T_1 - T_0}{T_1} = 0{\cdot}25.$$

The difference 264 — 248 = 16 is about $\frac{6}{100}$ of 248, which last value is nearly correct, for more exact formulæ give about 250 heat units. This is a fair approximation for an empirical formula and shows that 1·135 is not far from the proper mean exponent for the range of pressure occurring in this example; when the exponent is taken equal to 1·13, the two methods give the results 251 and 250 respectively, the result obtained from the indicator diagram varying least for a given change of exponent.

It is difficult to understand why Prof. Thurston should have chosen the exponent that he has done in this discussion, although it is evident that the use of a large exponent is necessary for the establishment of his proposition—that the efficiency of the ordinary type of engine can be greater than $\frac{T_1 - T_0}{T_1}$. He has chosen the highest adiabatic exponent for steam that can be found, namely that for superheated steam, and assumes that it is also applicable to saturated steam. He justifies this course by referring to what is obviously an oversight in Prof. McCulloch's valuable text book, in which the erroneous statement occurs, that Zeuner has determined the value of the exponent of the abiabatic curve for saturated steam to be equal to $k = \frac{4}{3}$, and that M. M. Cazin and Hirn have confirmed this result by experiment. That this statement is an oversight is evident from the facts, that it occurs under the head of superheated steam, that Zeuner has determined the exponent for the adiabatic curve of superheated steam to be equal to $n = \frac{4}{3}$, and that M. M. Cazin and Hirn's observations were made on superheated steam and not on saturated steam.* The doubtful propriety of accepting the conclusion to be drawn from the error above noticed, Prof. Thurston himself seems to have recognized, for in a foot-note he says: "This value of k [$= \frac{4}{3}$] may have been here accepted on insufficient authority, however, as Zeuner in his treatise (French ed. p. 332) makes it 1·135, and Grashoff makes it 1·14. Zeuner also shows that the value of k is reduced by the addition of water to the steam."

The addendum with which Prof. Thurston ends his paper is also devoted to this exponent matter, and we find that he there misapplies the results of the valuable experiments of Mr. J. Hoadley† for determining the exponent of the *compression* curves of a quick-running portable engine, by assuming that these experiments answered the purpose of determining the exponent k of the adiabatic curve of *expansion* of dry saturated steam. The large exponent (nearly $\frac{5}{4}$) shown by these experiments was supposed by the Professor to indicate that $\frac{4}{3}$ would be the value of k if the cylinder were a perfect non-conductor. The correct inference from these experiments would have been that the adiabatic exponent for saturated steam must be less, and that for superheated steam greater than 1·2366 (the exact value obtained by Mr. Hoadley). This value is almost exactly the mean of the two exponents 1·135 and 1·133 deduced by Zeuner for saturated and superheated steam respectively; the coincidence is, however, an accidental one, for only an intermediate exponent, not necessarily an exact mean, is to be expected from the compression curve of a high speed engine, the steam being wet at the beginning and superheated at the end of the compression.

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* See Mechanical Theory of Heat" p. 230 by Prof. R. S. McCulloch.

"Theorie de la Chaleur" p. 445—Zeuner.

Hirn and Cazin—Mémoire sur la détente de la vapeur d'eau surchaaufée. *Ann. de Chim. et de Phys.*, 4 serie T 10, p. 349–370.

† The Curve of Compression of the Steam Engine, by J. C. Hoadley. JOURNAL OF THE FRANKLIN INSTITUTE, Jan., 1878.

In a chapter on the Philosophy of the Steam Engine, the latest thing he has written on the subject, Prof. Thurston still uses the excessive exponent $\frac{4}{3}$, and again gives the foot note just quoted, accompanied, however, by the additional remark that Zeuner gives $\frac{4}{3}$ for superheated steam. This would seem to make it necessary either to prove Zeuner wrong or to abandon the use of $\frac{4}{3}$ for the adiabatic curve of wet steam—but the Professor has done nothing of the kind.

III. *That air an gas engines have been built whose theoretical efficiency was equal to unity; all unutilized heat being restored to the working substance by means of a mass of metal called a "Regenerator."*

This evidently supposes that all the unutilized heat, *i. e.*, all the heat abstracted from the gas, is taken up by the " regenerator, but this is a mistake, only a part is thus stored even when the regenerator is perfect in its action, the remainder, that, namely, which is abstracted during compression at the lowest temperature, being permanently rejected by being discharged into the atmosphere by conduction,* or into a refrigerator specially prepared for the purpose. Dr. Barnard and Rankine were the first to point out that the efficiency of an engine with regenerator was not greater than that which received and discharged heat only at its upper and lower limits of temperature respectively, that the true office of the regenerator was to raise and lower the temperature of the working substance, and that it accomplished this result in a less bulky manner than was possible by the contraction and expansion of volume without transmission of heat.

IV. *It is theoretically possible to have a " new type of steam engine" which will perform work without rejecting heat by returning the working substance to the boiler in a peculiar manner.*

In this new type of engine, *all* heat not utilized by transformation into work was to be returned to the boiler instead of being rejected and wasted during the exhaust, as in the ordinary type of engine; nothing being lost as heat, the engine must be theoretically capable of utilizing the full mechanical equivalent of the heat energy supplied without any regard to its range of temperature. For achieving this result the new engine was to have two compressing pumps, in which, after expansion had taken place in the working cylinder, the water of condensation and the uncondensed vapor were to be separately returned to the boiler. The energy expended in returning being practically that of returning the uncondensed steam, it was assumed that the latter "would involve not only the return of the charge of heat contained in that steam, but also the return of all the energy which the vapor had yielded during its expansion, since an equivalent amount of heat would be generated by its compression to boiler pressure." Now this last must mean that the *wetness* of the steam during expansion, and its dryness or superheated condition during compression, is here of no consequence whatever, the work of compressing the dry uncondensed steam to boiler pressure being always equal to the work performed by an equal weight of the saturated steam whilst expanding in the non-conducting cylinder. Were this correct, the Professor's conclusion would follow, that "The ratio of the total work done in restoring unutilized heat, to the work done by the steam on the piston, would be in the ratio of the weight of uncondensed steam returned to the boiler, to that supplied to the working cylinder at each stroke." A surplus of of energy would thus be left to be utilized for mechanical purposes. That the steam would be superheated during compression does not seem to have been entirely ignored by the Professor, but it was assumed to

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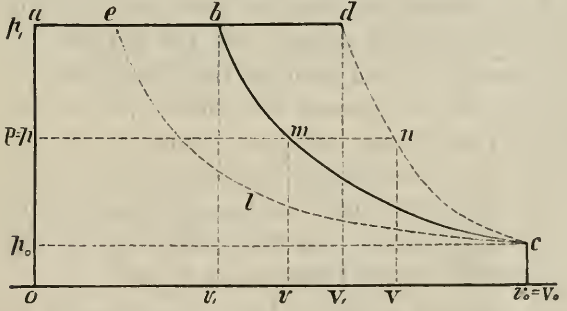
* Loss of heat by conduction in this part of the process must not be prevented even in a perfect engine, for it is an absolute necessity if work is to be produced.

Fig. 4.



be a condition that would be favorable instead of fatal to the efficiency of the "new type of steam engine." This was because undue influence was ascribed to the comparatively slight increase of pressure that would occur if the water of condensation were present and were re-evaporated during compression, while the preponderating influence of the high temperatures of the superheated steam in increasing the resistance to compression was either neglected or entirely lost sight of.

The indicator diagram of the new type of steam engine, as given by Prof. Thurston, is represented by *abcea* (Fig. 4), where *b* is the point of cut off, *bmc* the adiabatic curve of expansion, *c* the point at which the water of condensation is separated from the uncondensed steam, *cb* the supposed adiabatic curve of the compression of uncondensed steam, and *ebce* the area representing the surface of energy that may be used for mechanical purposes.

We have already, in a general way, pointed out the fallacies involved in supposing that the work of returning the uncondensed steam to the boiler can be less than that done by the steam whilst entering the cylinder and expanding, but will now give a more detailed examination to this matter, and will show that in the "new type of steam engine" the work expended must always be greater than the work produced. To do this it will only be necessary to show that the curve of compression of the uncondensed steam falls above the expansion curve *bmc*, which latter may also be regarded as the curve of compression of the mixture of water and steam which exists in the cylinder at the end of the expansion; for if the water of condensation be not removed, compression without transfer of heat will cause the curve *cmb* to be retraced, leaving the fluid in the condition of dry saturated steam at the point *b*.

That the curve of the uncondensed steam lies above that belonging to the mixture of water and steam can be shown by employing the formulæ for the adiabatic curves of saturated and superheated steam, respectively, $p\ v^{k} = p_1\ v_1^{k} = p_0\ v_0^{k}$, $P\ V^{n} = P_1\ V_1^{n} = P_0\ V_0^{n}$

In the first of these two expressions v, v_1 and v_0 must be understood as representing the volume of a unit of weight of the mixture of water and steam when at the pressure p, p_1 and p_0 respectively; while in the second expression V, V_1 and V_0 represent the volume at the respective pressures P, P_1 and P_0 of that fraction of a unit weight which existed as dry uncondensed steam at the end of the expansion, or beginning of the compression. The various values of k when the steam is dry saturated at the beginning of expansion have already been given in the foregoing table, and were there seen to differ but slightly from Zeuner's mean value, 1·135. Zeuner has also called attention to the fact that Rankine's value for $k = \frac{10}{9}$ is only applicable when the steam at the beginning of expansion contains about 25 per cent. of water, and that when the steam contains 68 per cent. of water at the beginning of expansion, its curve will become approximately that of an equilateral hyperbola, for the exponent of k will then equal unity. The exponent n of the second formula has been assumed by Zeuner to be equal to $\frac{4}{3}$, which is nearly correct, even within finite and practical limits, for the experiments of Hirn* give values of n which vary from 1·29 to 1·31 and increase with the degree of superheating. There is, moreover, reason to believe that $\frac{4}{3}$ is the limiting value of the adiabatic exponent of every superheated vapor where molecules are composed of three atoms.†

If we apply these two formulæ to the "New Type of Steam Engine" and neglect, as before, the volume of the water of condensation, we get

$$V_0 = v_0. \quad P_0 = p_0; \quad \text{also} \quad V\left(\frac{P}{p_0}\right)^{\frac{1}{n}} = v\left(\frac{p}{p_0}\right)^{\frac{1}{k}}$$

In order to determine which of the two curves lies above the other, we have only to compare their volumes when they have the same pressure, for the greater volume will belong to the higher curve, as in Fig. 4, when of the two volumes *pm* and *pn*, the greater *pn* belongs to the higher curve *cnd*. If, therefore, we assume $P = p$ we shall have

$$\frac{P}{p_0} = \frac{p}{p_0} > 1$$

$$\text{and} \quad \frac{V}{v} = \frac{\left(\frac{p}{p_0}\right)^{\frac{1}{k}}}{\left(\frac{p}{p_0}\right)^{\frac{1}{n}}} \qquad (8)$$

from which follows that V will be greater than v, when the numerator of the second member of equation 8 is greater than the denominator, *i. e.*, when the exponent k is *less* than the exponent n.

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* Hirn and Bazin, Mémoire sur la détente de la vapeur d'eau surchauffée.—*Ann. de chim. et de phys.*, 4 Serie, vol. 10, pp. 349—370.

See, also, Rühlmann, "Handbuch der Mechanischen Wärme Theorie," p. 710.

† See Wüllner, "Experimental Physik," p. 530.

Since *all* the experimental evidence bearing on the matter goes to show that

$$k < n \leqq \tfrac{4}{3}$$

we must conclude that the curve of compression of the uncondensed steom lies above the curve of expansion *bmc* and that consequently the work of returning the uncondensed steam to the boiler must be *greater* than the work which the steam can perform whilst entering the cylinder and expanding; in other words, the "New Type of Steam Engine" is worse than worthless, for it will not drive, it must be driven, it is not a motor but a heat generator, and instead of having an efficiency equal to unity it has an efficiency which is represented by a *minus* quantity.

That the performance of this engine does not improve (as Prof. Thuston seems to think) with greater range of pressure, is shown by the following table which gives the ratio of the work expended to the work produced:

In the "New Type of Steam Engine" $\dfrac{\text{work expended}}{\text{work produced}} =$

Exponents of adiabatic curve for		Ratio of final to initial pressure.			
saturated steam	superheated steam.	$\frac{1}{2}$	$\frac{1}{8}$	$\frac{1}{32}$	$\frac{1}{128}$
k	n				
1·135	1·300	1.017	1·093	1·194	1·316
1·13	1·133	1·020	1·109	1·230	1·381
1·00	1·133	1·038	1·210	1·459	1·787

The values of this table were obtained as follows:

$L =$ work produced $=$ area $(o\,a\,b\,r_1 + r_1\,b\,c\,r_0) = p_1 r_1 +$

$$\frac{p_1 r_1}{k-1}\left[1 - \left(\frac{p_0}{p_1}\right)^{\frac{k-1}{k}}\right]$$

$L_2 =$ work expended $=$ area $(o\,a\,d\,V_1 + V_1\,d\,c\,v_0) = p_1\,V_1 +$

$$\cdot\ \frac{p_1 V_1}{n-1}\left[1 - \left(\frac{p_0}{p_1}\right)^{\frac{n-1}{n}}\right]$$

If now we divide the last equation by the first and reduce by means of equation 8, making $\frac{p_0}{p_1} = r$, we shall have

$$\frac{L_0}{L_1} = \frac{(k-1)\,(n\ r^{\frac{1}{n}} - r)}{(n-1)\,(k\ r^{\frac{1}{k}} - r)}$$

and when $k=1$, we have $\frac{L_2}{L_1} = \frac{n\qquad r^{\frac{1}{n}} - r}{r\,(n-1)\,(1 + \text{hyp. log.}\,\frac{1}{r})}$.

This closes our examination of the errors enumerated at the beginning of this dicussion ; it has shown us that the special arguments advanced in support of the thermodynamic fallacies are worthless, that they contain nothing which can throw doubt on the demonstration that $\frac{T_1 - T_0}{T_1}$ is the expression for the maximum efficiency of all possible heat engines.

NOTE.—The scale of absolute temperature is due to W. Thomson, who has given two equivalent definitions of it, of which the first is :

"*The scale of absolute temperature is the reciprocal of Carnot's Function.*"

Expressed analytically, this is :

$$T = \frac{1}{J\left(\frac{d\,Q}{d\,v}\right)_t \div \left(\frac{d\,p}{d\,t}\right)_v}$$

where J is Joule's equivalent, $\left(\frac{d\,Q}{d\,v}\right)_t$ is the rate at which the heat (furnished to or abstracted from the body) varies with the volume when the temperature remains constant and $\left(\frac{d\,p}{d\,t}\right)_v$ the rate at which the pressure varies with the temperature when the volume is constant.

The second member of this equation can be obtained from the properties of any body, and is remarkable in varying only with the temperature, having the same value for all substances that have the same temperature and is therefore to be regarded as a function of the temperature only. At first it was feared that this function might be difficult to express in terms of the readings of the ordinary standards, but experiment showed that the numerical values of this function did not differ essentially from the readings of a standard air thermometer whose freezing and boiling points were respectively marked 273·7° and 373·7°. The reciprocal of Carnot's Function was therefore seized upon by Thomson as a suitable means of expressing temperature absolutely, *i. e.* independently of the properties of any particular substance. This function, it should be remembered, was deduced from the cycle of Carnot's engine when working with an infinitely small range of temperature; from this follows that the above definition of absolute temperature is equivalent to the following, also given by Thomson:

"*The absolute values of two temperatures are to one another in the proportion of the heat taken in to the heat rejected in a perfect thermodynamic engine, working with a source and refrigerator at the higher and lower temperatures respectively.*

Analytically expressed, this is:

$$\frac{Q_1}{Q_0} = \frac{T_1}{T_0}$$

from which we can get

$$\frac{Q_1 - Q_0}{Q_1} = \frac{W_1}{J\,Q_1} = \frac{T_1 - T_0}{T_1}$$

and from this follows that equal differences of absolute temperature represent equal quantities of work performed in a perfect thermodynamic engine.

Imitation Ebony.—Oak may be dyed so as to resemble ebony by soaking it for forty-eight hours in a hot saturated solution of alum and then painting it with a decoction of one part Campeachy wood in eleven parts water. This decoction should be first filtered and slowly boiled down to one-half its volume, when ten to fifteen drops of neutral indigo tincture should be added to every quart. After the application of this solution the wood should be rubbed with a saturated solution of verdigris in acetic acid. The operation is to be repeated till the desired tint is obtained.—*Der Techniker.* C.

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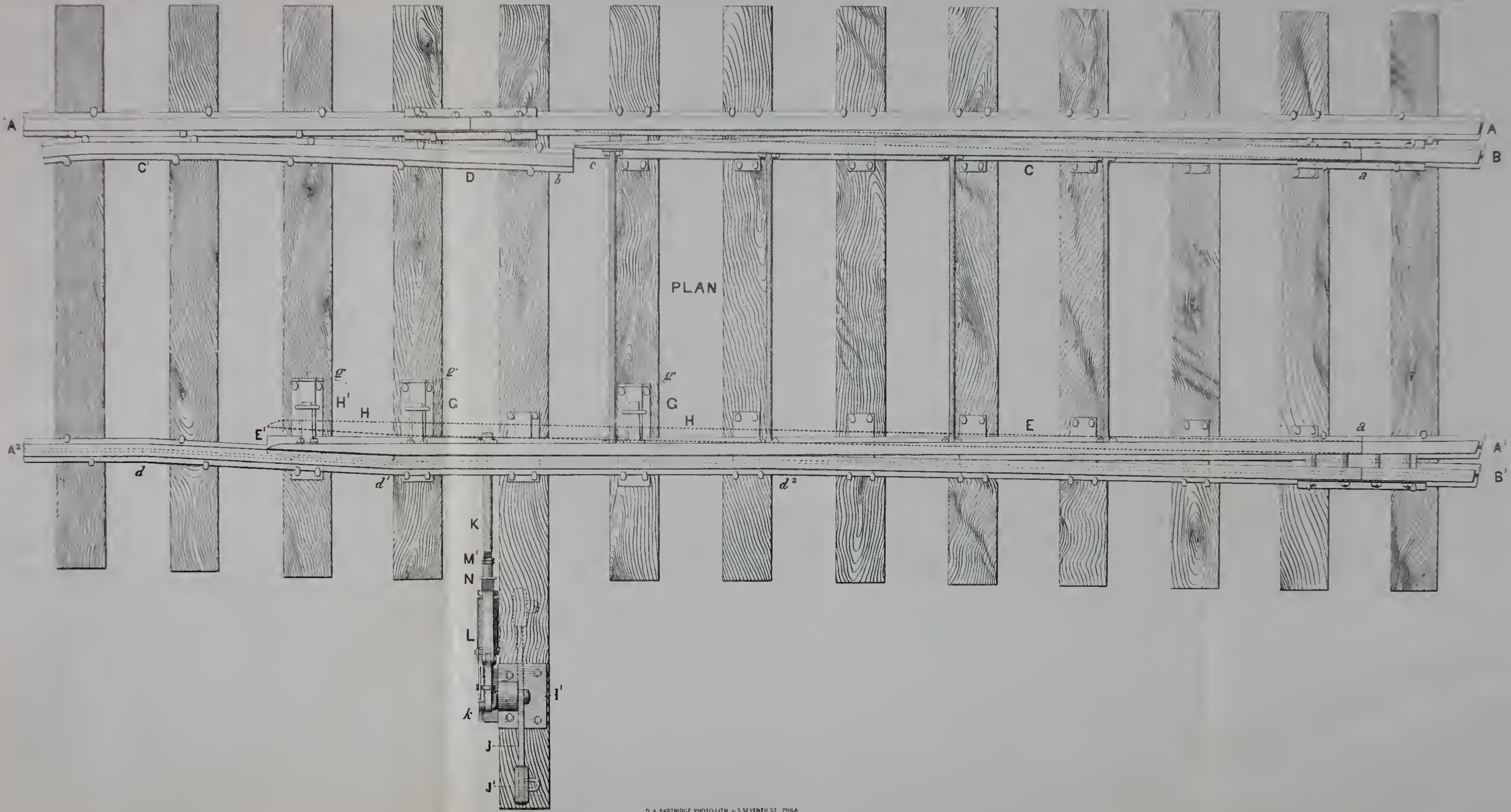
AINSWORTH'S AUTOMATIC SAFETY SWITCH.



D. A. PARTRIDGE PHOTO-LITH 22 S. SEVENTH ST. PHILA.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON AINSWORTH'S AUTOMATIC SAFETY-SWITCH FOR RAILROADS.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, Nov. 29th, 1878.

The Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination Ainsworth's Automatic Safety-switch for Railroads, report that they have carefully examined the switch itself and the inventor's plans, specifications and model, and find that this switch belongs, generally speaking, to the same class as the Lorenz or English switch, but differs from all other switches known to your committee in several important respects. The invention may be divided, for the purposes of this report, into two separate parts: the switch proper and the switch stand, or mechanism for moving the switch. Referring to the accompanying cut (No. 1), it will be seen that in this switch the outer rail of the main line, A A (the rail farthest from the siding), is unbroken or continuous; while the inner rail of the main line, A^2B^1, is bent slightly at d, resumes its former course at d^1, and continues to d^2, the amount of the deflection, d d^1, being equal to the width of the head of the rail. At d^2 the rail bends again, and from thence continues in a long curve, forming the inner rail of the siding. These rails (A A^1 and A^2 B^1) are fixed and continuous; but between them are two pointed rails (C B and A^3 E^1), joined rigidly together by proper rods, so that when one point is against the nearest rail the other point will stand off from its rail a distance of four (4″) inches. These moveable rails or points are so placed that E^1 is considerably in advance of C, and both are shaped to fit against the fixed rails at one extremity, and are secured at their other ends by fish plates, so that a movement of these rails in one direction or the other will cause an approaching train to continue on the main line or be shunted into the siding.

In addition to the principal parts already enumerated, there is also furnished a guard rail, C^1 D. It will be seen that the switch rail, E E^1, has its point advanced such a distance before the point of the other switch rail (C c), that it will catch the flange of an approaching wheel and determine its direction before the other wheel on the same axle has reached the other point; and, moreover, as this projecting rail is comparatively blunt, and has its base but little diminished in breadth, it presents a good bearing for trains passing on the main line, and as its inside edge coincides with the inside edge of the main line, and its height is the same, trains pass the switch without jar. When the switch is set for the siding, the advanced point of $E\ E^1$ catches the flange of the approaching wheel, and, acting as a guard rail, forces it into the siding, but, at the same time, prevents the opposite wheel from striking the other point, and thus relieves that point of all work at its extreme end; while, in the case of trains leaving the siding, the guard rail, $C^1\ D$, catches the flange, and, guiding the wheels, prevents the flange from striking the offset, $d\ d^1$, in the rail, $A^2\ B^1$, which might otherwise suffer from the work that would be put upon it. The rail $E\ E^1$ is rolled $\frac{1}{4}''$ less in height than the other rails of the switch, and its flange is curved by the smith to fit on the upper surface of the flange or base of the fixed rail $A^2\ B^1$, so that, without diminishing materially the width of the base of $E\ E^1$ the two rails are brought together, and the base of $E\ E^1$, riding up on that of $A^2\ B^1$, distributes the weight of the train partly over the base of the fixed rail ($A^2\ B^1$) and partly over the iron plates upon which the moving rail $E\ E^1$ slides. In order that the point $E^1\ H$ may retain its position with reference to the offset in $A^2\ B^1$, regardless of changes of temperature, these two rails are bolted at one end to the same iron casting (a), and are thus compelled to expand and contract together.

The switch-stand (shown in cut No. 2) contains a cranked shaft operated by a weighted lever and joined by a suitable connecting rod with the moveable switch points. A movement, therefore, of the weighted lever through a semicircular arc serves to open or shut the switch, and the connecting rod contains an adjustable spring which will permit a train leaving the siding to spring the rails over sufficiently to pass, and yet has tension enough to draw the points back into position to leave the main line clear. In these respects it is similar to the Lorenz switch-stand; but, furthermore, it is so arranged that when it is set for the siding, and a train passes on the main line in the direction towards which the points open, the wheels will not simply force the switch shut by compressing the spring, but will cause a friction roller on the extremity of the switch or connecting rod to move up an inclined plane, bringing a second friction roller under the crank, and thus lifting it over the centre. The counterweight on the lever, by its weight and momentum, completes the movement with some force, and thus, by

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a positive motion, the first pair of wheels of a train on the main line moving in the proper direction of travel, closes the switch, that is, sets it for the main line.

This switch has also another essential peculiarity. In other similar stands the elasticity of the connections remains constant, and is sufficient to enable the switch-tender to throw the lever into place although the switch-points may be held from the rail by accumulations of snow or ice, or by stones from the ballasting, and the switch may thus be left in a most dangerous condition; but Ainsworth's switch is so made that during the act of closing or opening it, and until the points are moved quite into place, the connections between the stand and the points become, for the time being, rigid, or non-elastic, and it is impossible to shove down the ball on the switch-lever until the points are entirely home; and the throw of the crank is great enough to permit the switch to be moved before the end of the arc is reached. This important result is accomplished (as shown in cut No. 2 herewith) by means of a slotted plate (*a*) in which works a pin (*b*) attached to the end of the switch-rod: During the act of shifting the switch, this pin remains against a shoulder in the slot, and any change of length in the switch-rod is prevented; but, at the conclusion of the movement, the plate is moved by a positive motion into such a position that the pin may move along one of the slots to permit the points of the switch to be sprung over. It is thus rendered impossible for the switch-tender to leave the switch half open, if he puts the ball down and locks it in place, for, in order to do this, it is necessary that the switch be either open or shut.

In examining and testing this switch, your committee have had in view the fact that there are, generally speaking, four different conditions under which a "safety-switch" is tried in practice, and which it must fulfill in order to establish its claim of "safety." These conditions may be stated thus:—When the switch is set for the main track, it is essential, first, that it be safe for trains passing in either direction on that track, and, secondly, that trains must also be able to pass in safety from the siding to the main line. When the switch is set for the siding, trains must be able, thirdly, to pass into or out of the siding, and, fourthly, to pass along the main line in the direction towards which the switch opens. Your committee were enabled to test the Ainsworth Automatic Safety-switch in all of these particulars, and in every case found it to give most excellent results. In the first case just stated, trains must pass in either direction with perfect safety, for one rail remains entirely unbroken, and the flange of the wheel is compelled to follow it by the guard-rail, and by the outer switch-rail acting as a guard-rail to prevent wear on the points; and the inside-track rail also offers a practically continuous and sufficient bearing for the tread of the wheels. In the second case, the spring in the "switch" or "connecting" rod, acting as in the Lorenz and English switches, permits the outgoing train to move the points sufficiently to pass, and, after the passage of the train, the spring restores the points to their proper positions. This the committee tested repeatedly, by running trains through the switch at high and slow speeds, and with perfectly satisfactory results.

Under the the third head, that is, with switch set for siding, trains are permitted to pass safely in either direction. When they *enter* the siding, the advancing flange on the switch side of the track enters the four-inch aperture between the point and the rail; is diverted by the projecting point, and, before the opposite wheel has reached the other point, the inside wheels will have obtained a good bearing on the bent or continuous switch-rail, and the open main-track rail acts as a guard to prevent wear on the point of the open switch-rail; while, in case of trains leaving the siding, the flange is caught by the guard-rail, and the wheel is diverted on to the main-line unbroken rail before the opposite flange has reached the bend in the continuous switch-rail. And, fourthly, trains passing against the points will, of course, enter the switch, while trains passing with the points, or in the proper direction of travel, will continue on their course, and continue without interruption or jar; but the first pair of wheels to enter the switch will close it, and the train will leave it set for the main line by the mechanism previously described.

As this is a feature possessed by no other switch known to your committee, especial pains were taken to note its action under repeated experiments, and the committee are satisfied that it is certain in its operation and fully sustained the inventor's claims. But, besides the foregoing legitimate cases, we must consider the possibility of maliciously or accidentally setting the switch wrong. As we have seen, it is impossible that the switch be left in a dangerous position if the lever be put in either of its extreme positions; but, suppose the lever not pushed to place, but standing upright or blocked in some intermediate place, will it cause a train to leave the track? To try the effect of this, the switch-lever was raised to about a central position, and the train was run at the points. Under these circumstances it was found that the wheels would invariably take one side or the other of the point, and turn into the siding or continue on main track. If the flange of the wheel be as sharp as usual, it follows that the wheel must take one side or the other of the point; but if the flange be sufficiently broad, it is possible that it might strike the point so directly that the wheel might ride up on the point; but, even if it should, no harm could result, because the opposite flange would be guided by the guard-rail and the other point. The working parts of the stand are protected from the weather or from mischievous interference by a stout wooden cover, and, as we have already seen, it is impossible for the switch-tender to set the switch-lever "home" in either position unless the points are also in their proper positions. In all of these respects the switch worked admirably, and there does not appear reason why it should not be at least as durable as any other safety-switch in the market. It is sufficiently simple in its construction, and may be manufactured quite as cheaply as other switches of its class, especially as it requires but little machine-shop work or fitting to construct it. Its most complex part (the stand) consists chiefly of steel castings, which may be put together with scarcely any finishing. In conclusion, your committee have to report that they find that the Ainsworth switch sustains fully the claims made for it; that it performs its work surely and satisfactorily, and seems to possess reasonable durability; and they welcome it as a successful effort to diminish the danger of what has proved the most prolific source of railway accidents.

O. B. Colton.
Thos. Shaw.
Wm. D. Marks.
Coleman Sellers, Jr.,
Chairman.

Approved by the Committee on Science and the Arts, March 5, 1879.

Henry Cartwright,
Chairman pro tem.

Air-tight Corks.—Plunge the corks in melted paraffine and keep them there for about five minutes. Corks thus prepared can be easily cut and bored, and easily inserted or withdrawn from the bottles. They are both air-tight and water-tight.—*Der Techniker.* C.

REPORT OF THE COMMITTEE ON SCIENCE AND ARTS ON NORBERT DE LANDTSHEER'S MACHINE FOR TREATING FLAX, HEMP, ETC.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, Dec. 19th, 1878.

The Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination Norbert de Landtsheer's machine for treating flax, hemp and other similar plants, report that the machine occupies a floor space of about 8 by 10 feet, and consists of a cast-iron frame, a stationary feed-board or table, two pairs of fluted metal rollers, a sheet-iron drum or cylinder, furnished with blades or beaters of wood at regular intervals around its circumference, and the necessary driving pulleys, wheels, pinions and gears for automatic operation. In outward appearance it somewhat resembles a grain fan.

Two distinct operations upon the staple to be treated are performed by this machine: the first that of breaking, the second, of scutching. The object of the first is to break the stem or "boon" forming the woody interior of the flax, or other similar fibrous plant, that this refuse may more readily be removed in the subsequent operations. The second is to beat or "scutch" out this "boon" or broken straw, thus leaving the fibre in a condition to be mechanically divided in the heckling machine or gill-box.

In operation, the stalks of hemp or flax, which had previously undergone the process of "retting" or rotting, were placed upon the feed-table of the machine, and fed to the first pair of fluted rolls or cylinders in the direction of the fibre's length. These fluted rollers are each supported in journal-boxes, which allow the teeth or flutes to mesh, but prevents them from coming in contact at the bottom of the flutes. To these rolls or cylinders is imparted, by suitable mechanism, an alternate circular motion, forward in the direction of the scutching-drum and backward in the direction of the feed-table, the forward motion being the greater. This, while imparting a reciprocal movement to the fibrous stalks, thus effectually breaking the "boon" or woody interior, at the same time carries the "strick" or broken portion forward to be still further operated upon by the scutching-drum or cylinder.

This drum is of sheet-iron, affixed to cast-iron rims or spiders, is four feet in diameter and is furnished with sixteen tough wooden blades or beaters. It revolves in an opposite direction to the forward motion of the breaking rollers; that is, the upper periphery of the scutching-drum moves in the direction of the feed end of the machine, thus bringing its beaters with a downward blow against the pendant fibres, beating out the "boon" or broken woody interior. This operation is still further aided by the current of air set in motion by the revolution of the drum which winnows the chaff from the long lines of fibre.

When the stalks have been fed between the fluted rolls to a little beyond the centre of their length the alternate circular motion is converted automatically or by hand to a rapid continuous reverse motion, which delivers to the operator who then feeds the unbroken stalk ends to the breaking rolls. These in turn undergo the above-described operations and the fibre, discharged as before, free from straw or "boon" and in straight, untangled lines.

The mechanism designed to impart the alternate circular and continuous reverse motions to the fluted rollers consists, in its essential features, of a concentric pinion-wheel brought into alternate working contact with cogs on the concave rim of a surrounding gearing and a system of crossed and open belts. This mechanical contrivance is deserving of special mention, being well adapted for the purpose designed, is capable of adjustment to suit different lengths of fibre, and may be controlled automatically or by hand.

The flax stalks operated upon, were grown not for the fibre, but for seed alone, and had not been properly "retted"; yet the machine under consideration performed the operations of breaking and scutching with entire success. Flax stalks, two feet, and hemp stalks eight feet long were alternately fed to the machine and the fibre was delivered clear of "boon," straw and woody material, in from thirty to forty seconds, while but very little scutching-tow or codilla was made.

The machine is rapid in its action, not complicated with delicate and nicely-to-be-adjusted parts, requires comparatively little power to drive and does not need skilled labor to operate it. It is a French invention, and letters patent have been granted in England and the United States, the former bearing date May 30th, 1874, and designated by No. 1900, the latter May 8th, 1877, and numbered 190,476.

The introduction and general use of this machine would without doubt tend to restore and extend the cultivation of such fibrous plants as flax, hemp, jute, and others of a similar nature, by enabling producers to deliver these several fibres in a clean, straight, long-line, marketable shape, at low cost.

Unlike cotton, which is comparatively a delicate plant that can only be grown profitably in the Southern and Southwestern States, flax and kindred plants may be grown readily throughout our entire country. Light soils are more suitable for its development, but good crops may be gathered from strong and clayey ground.

Hitherto the operations of breaking and scutching have been largely performed by hand. Where machinery has been used, each operation required a distinct and separate machine. Rude in design and imperfect in performance, they have, even in flax-growing districts, scarcely supplanted the primitive methods, while in this country they are almost unknown.

Your sub-committee therefore respectfully submit the above, and believe this machine to be a valuable and useful improvement, worthy of award.

STOCKTON BATES,
CHAS. H. BANES,
C. J. MILNE,
JOHN SHINN.

FRANKLIN INSTITUTE STANDARD SCREW THREAD.

We are in receipt of a letter from the Morse Twist Drill and Machine Co., of New Bedford, Mass., in reference to the standard for screw threads proposed by this Institute fifteen years ago. This letter we publish entire, but must venture some comments on that portion of it alluding to the difficulties to be experienced by manufacturers in originating their own standards. On page 247 will be found the assertion "If manufacturers establish their own standard, their work will not interchange either with one another or with the Government standards, by which the largest majority of the work has thus far been constructed." The so-called Government standards are the sample screws and threaded collars purchased by the Navy Department for certain of the Navy Yards. These were made by a Mr. Fox, and may or may not be correct in diameter in angle of thread or in the width of flat top and bottom. They are said to have been made according to the formulæ prepared by Mr.

William Sellers and adopted by the Institute. What is claimed for these formulæ is that they offer rules to guide workmen of ordinary intelligence to originate each for himself work that would interchange with the work of the makers. We do not think that the same accuracy of fit is required in bolts and nuts as is looked for in standard plugs and rings for determining size. A reasonably good fit for a bolt and its nut is a long way off from the fit of these standards and yet answer a very good purpose. It is quite certain that interchangeable work in the line of bolts and nuts have been originated by manufacturers widely separated from one another. What we are anxious to see in relation to the new standard is good instruments for determining the accuracy of the taps in the market in the hands of the users of the tools, so that they can themselves judge of the correctness of the work furnished to them.

The suggestions made by Mr. Stetson in his letter in regard to the use of $\frac{1}{32}$ and $\frac{1}{64}$ size taps is very well worthy of careful consideration. These odd sizes are used in place of the even inch quarters and eighths in order to take less stock off of certain over size irons in the market. Thus some bolt makers tap one inch nuts with a tap $1\frac{1}{64}$ inches diameter and cut the bolts to fit this even size. Now, not long since Mr. Whitney, of Pratt & Whitney, also tap and die makers, was told by the manager of one of the principal railroads in New York State, that the saving in expense to that road in bolt-iron only would amount to several thousand dollars a year if they should be particular to buy only iron rolled to proper size. Rolling mills can readily furnish the sizes wanted when they know the need of the accuracy. We quite agree with Mr. Stetson that these over sizes should not be classed as "Standard." S.

"NEW BEDFORD, MASS., February 10th, 1879.

"*To the Committee on Publication, Franklin Institute, Philadelphia:*

"GENTLEMEN :—It is now the fifteenth year since the adoption of the report of your committee recommending a system of threads for screw work. It may be interesting to call attention to the subject to keep it before the public, and to know how its adoption is progressing. Its value can be somewhat shown by stating that a full set of hand and nut taps ranging from $\frac{1}{4}$ in. to $1\frac{1}{4}$ in. of the common form and number of threads requires 246 taps, while the same sizes by the Franklin Institute standard require only 48 taps. The loss between the systems in time and money must hold somewhat the same proportion. The adoption of a system of threads that would be interchangeable requires very accurate work, as the construction of common cylindrical gauges is a test of good workmanship. The surfaces of a 1 in. plain gauge, however, are but about one-half as large as in a threaded gauge. A 1 in. plain gauge fitted to a 1 in. broad ring has three and a fraction square inches of bearing surface. A 1·8 threaded gauge has nearly six square inches bearing surface. The plain gauge is readily ground after hardening ,the threaded gauge, though more liable to change in hardening, can only be re-adjusted by a system of grinding producing approximate results. The contraction of taps and dies in the hardening process is the most serious matter that stands in the way of interchangeable work. Two taps made at the same time and size will frequently fit quite differently after tempering. The cause can be shown by an instrument made of sheet steel, fitted to an accurate thread, the points being two inches apart and of the proper angle. It is used by placing the points in the thread parallel with the grooves. Few taps will be found perfect when subjected to this test, which shows their contraction. This tool would be useful to bolt makers as a dull, thin or contracted die changes the lead of the thread and makes an element of inaccuracy difficult to contend with. Hardened taps cannot be gauged with accuracy, as their changes in hardening will not allow them to be returned to the gauge they were cut to. The best way is to provide a standard male gauge to inspect the work tapped by them. With the above facts in view it can be seen how much care the adoption of a standard of reference requires. The general government, seconding the efforts of the Franklin Institute, caused to be made ten sets of standard gauges to be used in the several navy yards. These gauges embody all the principles recommended in the report of your committe, the female gauge being the proper thickness and form of the nut recommended. The male having the size at the root of thread shown by a projection of a portion of the point, turned to the proper diameter beyond the thread. The government work has been made in conformity to these gauges for several years since their acceptance. At the time the system was established, the manufacture of taps and dies (for the market) was in an undeveloped state; the manufacturers being unable to produce work to meet the requirements of the system. At the purchase of the tools and machinery of the New York Tap and Die Company by the Morse Twist Drill and Machine Company, in 1874, an effort was made to furnish the public with tools, enabling its general adoption. Their experience in constructing gauges of the common threads had shown them that the construction of a set of gauges to measurements, that would interchange with others constructed to a common standard, would be very difficult, if not practically impossible. Learning of the sets owned by the government, they procured a full set, their duplicates, which being tested at the Navy Yards at Charlestown and Brooklyn, proved to interchange satisfactorily. Feeling that they were now able to construct tools in conformity with the already recognized standards, they were placed upon the market. The demand has steadily increased, and several of the largest railroads are constructing their work on this principle and demanding their contractors to conform thereto. The larger companies are adhering to the standards, but there is a constant tendency to destroy the perfection of the system by orderin $\frac{1}{32}$d and $\frac{1}{64}$th sizes. Also, frequently the number of threads is changed but the shape ordered retained. Such departures would seem to be unnecessary, and destructive to the best results. Iron can be procured of accurate sizes when demanded. Engineers and manufacturers should be sufficiently alive to their own interests to discountenance any unnecessary deviation from the standards.

"To make screw work interchangeable will require careful supervision and accurate gauges. If manufacturers establish their own standards, their work will not interchange either with one another or the government standards, by which the largest majority of the work has thus far been constructed. The causes that have delayed the adoption of the system are apparent and have been removed. Its adoption by the Navy Department, Master car builders and several of the larger constructors, its increased use by the general public give assurances that promise well for its rapid and general adoption.

"George R. Stetson."

Important Triangulation.—One of the greatest trigonometric works that have ever been undertaken is the union of the Spanish and Algerian Surveys. The Spanish engineers are stationed in the Sierra Nevada and upon Mt. Tetica; the French at Fillaoussen, near Nemours, and at Ben Sabra, near Oran. The latter are under the orders of Commander Perier, of the Bureau of Longitudes.—*Der Techniker.*

C.

STEAM-BOILER EXPERIMENT.

By Chief Engineer ISHERWOOD, U. S. Navy.

During an investigation of the effect of automatic steam regulating dampers, conducted by a Board consisting of the writer and Chief Engineers Zeller and Snyder, of the United States Navy, it became necessary to ascertain the exact economic vaporization of water by anthracite in the two boilers of the locomotive type furnishing steam for the machine-shop of the New York Navy Yard; and the results of the trials, together with a description of the manner of making them, and of the boilers, are given in this paper.

The two boilers, which are exact duplicates in all respects, are situated side by side in the boiler-house and have a steam connection in common, so that both are worked with precisely the same pressure, and they deliver their gases of combustion into the same chimney, which is also used for other purposes.

Each boiler is fitted with a steam-gauge and a glass water-gauge, and had a sensitive metallic pyrometer permanently placed in its uptake to denote the temperature of the gases of combustion emerging from the tubes. In the vertical descending flue of each boiler which led from its uptake to the horizontal flue conducting these gases to the chimney, there was permanently placed between the uptake and the damper, a U formed glass tube containing colored water and fitted with a sliding scale, so that the force of the draught could be measured by the height of the column of water supported by the excess of the atmospheric pressure over the pressure in the flue.

All the feed-water supplied to the boilers was first accurately measured in a rectangular tank of wood lined with sheet lead and having its bottom carefully leveled. The capacity of this tank up to its overflow, was 118·709 cubic feet; and it was filled by gravity with water from the mains of the city of Brooklyn's water-works. The bottom of the tank was on an open platform at a considerable elevation above the top of the boilers, so that all parts both of the tank and its connections were in open view. From the tank, the feed-water descended by gravity into a "heater" where its temperature was largely increased (from 42½ to 175 degrees Fahrenheit) by the exhaust steam from the non-condensing engine of the machine-shop; and from the "heater" it was pumped into the boilers by a small steam-pump. The steam from the boilers was used as fast as generated to work this engine and to heat the machine-shop. The temperature of the water in the "heater" was given by a thermometer permanently inserted in it.

MANNER OF MAKING THE EXPERIMENTS.

The experiments were two in number and made in exactly the same manner; they were, in fact, repetitional, and gave almost exactly the same results. The duration of the first was 10¾ consecutive hours, and of the last, made after an interval of six days, 11 consecutive hours, the aggregate being 21¾ hours, the totals and means of which will be found in the table hereinafter given.

During these experiments, and for some weeks previous, the tubes were not swept, but the soot upon them was light. Neither had the water-side of the heating surfaces been cleaned for a considerable time, so that the boilers, as regards cleanliness, were in the condition of ordinary practice. They were perfectly tight, and well protected form heat radiation by a non-conducting coating.

The coal consumed was Pennsylvania anthracite of good quality, broken into pieces averaging 3 inches cube. It was accurately weighed in an iron tub counterbalanced on the scales, and filled each time to the same weight. The refuse from this anthracite was separated by screening into clinker and ash, each being weighed in the dry state in the same manner as the anthracite. During the experiments, the fires were not cleaned any further than could be done by revolving the Ashcroft grate-bars, which shook out some of the fine ash, but most of the ash and all of the clinker remained in the furnace until the end of the experiment. The furnace-doors were kept closed except when opened for throwing in the coal. The fires were maintained about 10 inches thick.

During the night preceding each experiment, a banked fire was kept in the boilers according to custom, and in the morning of the experiment it was thoroughly cleaned of ash and clinker, and spread over the grate-bars to the thickness of 3 inches. On this, the fresh coal was fired—the height of the water in the glass gauge having been previously adjusted—and the steam pressure and the time being noted, the 'experiment was held to commence. At its end, the fires were burnt out as completely as possible and then hauled, the steam pressure and water level having been made the same as at the commencement.

Whatever unconsumed coal was found in the hauled fires, was picked out, weighed, and deducted. The quantity of coal consumed by this method, included, of course, the 3 inches depth on the grate-bars at the commencement of the experiment.

During each experiment a tabular record or log was kept, in the columns of which were entered every fifteen minutes, the height of the barometer, the pressure of the steam in the boilers, the height of the water-column in each of the U shaped glass tubes measuring the force of the chimney-draught, and the temperatures of the external air, of the air in the boiler-room, of the feed-water in the tank, of the feed-water in the "heater," and of the gases of combustion in each uptake. The exact time at which each tankful of water was emptied was noted, and the depth of water drawn from the last tank.

The following is a description of one of the duplicate boilers on which the experiments just described, were made.

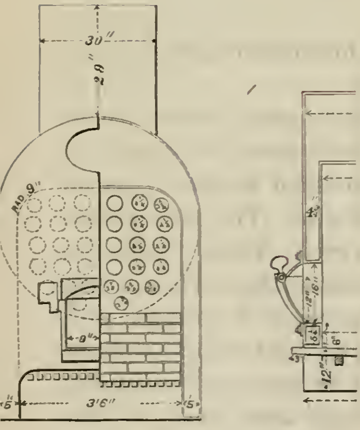
BOILER.

The boiler is of the locomotive type with fire-tubes extending horizontally in direct continuation of the furnace.

The front portion of the shell is rectangular in plan, 4 feet 4 inches in width, 8 feet 9½ inches in length, and 6 feet 6 inches in height: its top is semi-cylindrical. This portion of the shell is placed over an independent ash-pan of cast-iron 6 inches below it. The back portion of the shell, including the uptake, is cylindrical, 4 feet 4 inches in diameter, and 13 feet 9½ inches in length, making the extreme length of the entire shell 22 feet 7 inches. The upper half of the back portion is a horizontal extension of the semi-cylindrical top of the front portion. On the back portion of the shell is a cylindrical steam-drum, 30 inches in diameter and 29 inches in height above the top of the shell; it has a flat top to which the steam-pipe is bolted, and its axis is 10 feet from the boiler front. The entire shell and steam-drum are of ⅜ inch thick plate iron.

The boiler has one furnace, 8 feet long and 3 feet 6 inches wide in the clear: its sides are vertical, and its top, which is flat, is connected to them by quadrantal arcs of 9 inches radius. The front of the furnace is separated from the shell by flat water-spaces of 4⅞ inches width, including thicknesses of metal; and the sides of the furnace are separated from the shell by similar spaces, or water-legs, of 5 inches width, including thicknesses of metal. The lower part of the back of the furnace is separated from the shell by a flat water-space of 4¾ inches width, including thicknesses of metal; and the upper part of the back of the furnace forms the forward tube-plate.

The furnace-door is according to Ashcroft's patent; it is suspended from an axle at its upper edge and is counterbalanced on the opposite side, the ends of the axle being supported by pillow-blocks in project-

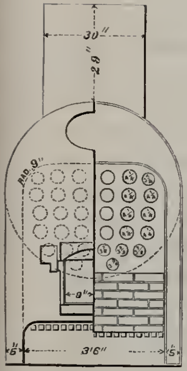


End View.

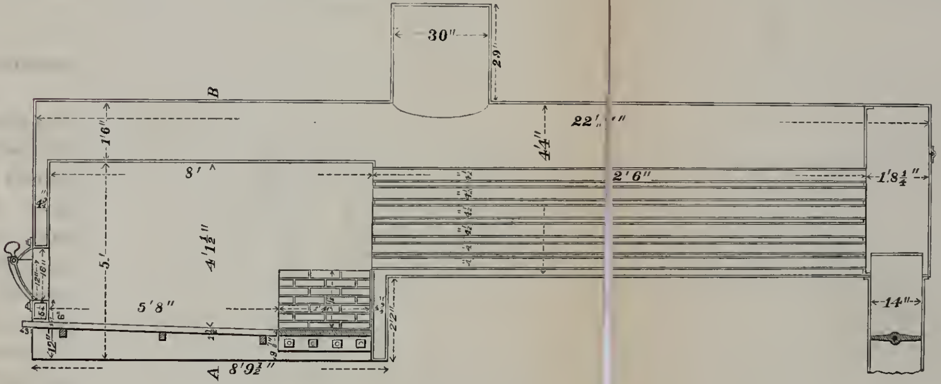
of 4¼ inches; all have an extreme length of 12 feet 6 inches from outside to outside of tube-plates which are ⅜ inch thick. The tubes are of ⅛ inch thick iron, and are secured by being expanded on the inner side of their plates and riveted over the outer side. They are arranged vertically,

STEAM-BOILER EXPERIMENT.

By Chief Engineer ISHERWOOD, U. S. Navy.



End View.



Sectional View.

furnace is separated from the shell by a flat water-space of $4\frac{3}{4}$ inches width, including thicknesses of metal; and the upper part of the back of the furnace forms the forward tube-plate.

The furnace-door is according to Ashcroft's patent; it is suspended from an axle at its upper edge and is counterbalanced on the opposite side, the ends of the axle being supported by pillow-blocks in projecting brackets from the door-frame. The door is thus made to open vertically instead of horizontally, as usual, and by means of the counterbalance to remain in any position in which it may be left. The opening for the door is rectangular, 18 inches wide and 16 inches high. The door is perforated with thirty-seven holes of $\frac{5}{16}$ inch diameter for the admission of air above the incandescent fuel; and during the experiment was kept closed except when coal was thrown into the furnace.

The grate-bars are, also, according to Ashcroft's patent, but are without the inclined dead-plate at the front which the patentee directs to be used in connection with them. The bars are nineteen in number, of wrought iron $1\frac{1}{2}$ inches square, and they protrude three inches beyond the boiler front, coming out with their upper surface six inches below the bottom of the door. The upper surface of the bars is four feet below the furnace-crown of the front, and four feet two and one-eighth inches below it at the bridge-wall. The air-spaces between the bars are 0·675 in. wide. The object of protruding the bars, as well as of making them square in cross section, is that they may be revolved on their axes by a socket wrench applied successively to their free ends, so as to clean the fire of ash without opening the furnace door. The bearers are crenated in semicircular grooves in order that the bars may not be dislodged in turning. The grate surface is 5 feet 8 inches in length, and 3 feet 6 inches in breadth, declining $2\frac{1}{8}$ inches from front to back.

The bridge-wall is of brick masonry, 15 inches high above the top of the grate-bars, level on its top, and 2 feet four inches in thickness lengthwise the boiler.

From the furnace to the uptake proceed in direct prolongation of the furnace, thirty-two horizontal fire-tubes, ten of which have an inside diameter of $3\frac{3}{4}$ inches, and the remaining twenty-two an inside diameter of $4\frac{1}{4}$ inches; all have an extreme length of 12 feet 6 inches from outside to outside of tube-plates which are $\frac{3}{8}$ inch thick. The tubes are of $\frac{1}{8}$ inch thick iron, and are secured by being expanded on the inner side of their plates and riveted over the outer side. They are arranged vertically, in six rows: the upper row contains four tubes of 4¼ inches and two of 3¾ inches inside diameter, the three succeeding rows contain, each, six tubes of 4¼ inches inside diameter; the next row contains six tubes of 3¾ inches inside diameter; and the lowest, or last row, contains two tubes of 3¾ inches inside diameter.

The uptake into which the tubes debouche, occupies the last 20½ inches of the length of the shell, and its extremity is fitted with a door hinged at its upper edge to give access to the back ends of the tubes for sweeping and repair. From the bottom of the uptake a vertical flue, rectangular in cross section and measuring 14 by 34 inches in the clear, descends several feet to a horizontal flue which leads to the chimney. The damper is placed in this vertical rectangular flue at 18 inches below the boiler-shell.

The entire shell, including the steam-drum, is covered with a 2 inches thick coating of asbestos cement, as a non-conductor of heat.

The following are the principal dimensions and proportions of the boiler, namely:

Extreme length of shell, ...	22 ft. 7 in.
Extreme breadth of shell, ...	4 ft. 4 in.
Extreme height of shell from bottom of ash pit, excluding steam drum, ...	7 ft.
Extreme height of shell from bottom of ash-pit, including steam-drum, ...	9 ft. 5 in.
Diameter of steam-drum, ...	2 ft. 6 in.
Length of grate-surface, ...	5 ft. 8 in.
Breadth of grate-surface, ...	3 ft. 6 in.
Area of grate-surface, ...	19⅚ sq. ft.
Number of tubes, ...	32.
Outside diameter of tubes,	Ten of 4 in. and twenty-two of 4½ in.
Inside diameter of tubes, .	Ten of 3¾ in. and twenty-two of 4¼ in.
Length of tubes in clear of tube-plates, . .	12 ft. 5¼ in.
Heating surface in the furnace . . .	99·182 sq. ft.
Heating surface in the tubes, calculated for their inner circumference, ...	426·464 sq. ft.
Heating surface in the uptake, . . .	8·354 sq. ft.
Total heating surface in the boiler, . . .	534·000 sq. ft.
Aggregate cross area of the tubes, . .	2·9343 s. ft.
Cross area of the vertical descending flue, . .	3·3056 s. ft.

Square feet of heating surface per square foot of grate surface, ...	26·9244
Square feet of grate surface per square foot of cross area of tubes, ...	6·7591
Square feet of grate-surface per square foot of cross area of vertical descending flue, . . .	6·0000
Extreme height of steam-room, exclusive of steam drum,	1 ft. 2 in.
Area of water level, ...	80 sq. ft.
Capacity of steam-room, including steam-drum, .	79 cu. ft.
Capacity of water room to 4 inches above crown of furnace, ...	160 cu. ft.
Distance traveled by the gases of combustion from the centre of the furnace to the centre of the uptake, .	17 ft. 4 in.
Height of the chimney above the level of the grate-bars,	83 feet.

With the boiler above described, and with the experiments made in the manner hereinbefore detailed, there were obtained the data and results given in the following table:

When one pound of the combustible, or gasifiable, portion of anthracite is burned to the complete oxidation of its constituents, the heat developed is sufficient to vaporize under the pressure of 29·92 inches of mercury, 15·4258 pounds of water having the temperature of 212° Fahrenheit. According to the above table, the vaporization realized under these conditions with the navy-yard boilers, was 10·0471 pounds of water per pound of the gasifiable portion of the anthracite, equivalent to an absorption of $\left(\frac{10{\cdot}0471 \times 100}{15{\cdot}4258} = \right)$ 65·132 per centum of the total heat, leaving 34·868 per centum lost by the heat in the gases of combustion entering the chimney, by imperfect combustion, and by external radiation. The latter was very small and may be neglected. The loss by imperfect combustion with anthracite when burned in a boiler-furnace with copious air supply, amounts to about $\frac{1}{100}$ of the carbon and $\frac{1}{12}$ of the hydrogen constituent, which reduces the heat developed by such combustion of one pound of the gasifiable portion of anthracite to the quantity sufficient for the vaporization of only 15·1541 pounds of water under the given conditions, making the vaporization realized by the navy-yard boilers equivalent to an absorption of $\left(\frac{10{\cdot}0471 \times 100}{15{\cdot}1541} = \right)$ 66·30 per centum of the total heat, leaving 33·70 per centum contained in the gases of combustion entering the chimney. The gases of combustion escaped from the boiler with the temperature of 533·5 degrees Fahrenheit, and as the temperature of the air in the boiler room was 71·6 degrees Fahrenheit, these gases carried off (533·5 — 71·6 =) 461·9 degrees Fahrenheit of temperature, representing 33·70 per centum of the total heat generated by the combustion; the initial temperature of these gases in the furnaces must, therefore, have been $\left(\frac{461{\cdot}9 \times 100}{33{\cdot}70} + 71{\cdot}6 = \right)$ 1442·2 degrees Fahrenheit. The temperature of the complete combustion of carbon and hydrogen with air of the quantity chemically required, is about 3600 degrees Fahrenheit; hence, approximately, $\left(\frac{3600{\cdot}}{1442{\cdot}2} = \right)$ 2·5 times that quantity of air passed through the furnaces of the experimental boilers.

In well-proportioned boilers consuming anthracite, the air supply does not exceed at the maximum twice that which is chemically necessary; the two and a-half times that quantity found above for the experimental boilers, was due to their too large calorimeter (1·0000 square foot of cross area of tubes to 6·7591 square feet of grate-surface) taken in combination with the fact that the tubes were not returned over, but lay in direct continuation of, the furnaces. The large calorimeter and easy exit of the gases of combustion prevented the pressure in the furnaces from being maintained sufficiently high to reduce the air supply to not over twice what was chemically necessary. In boilers of the experimental type, the calorimeter or opening through the tubes for draught, should not exceed one-ninth of the grate-surface. Had these boilers been so proportioned, their economic vaporization would have been not less than ten per centum greater.

Analogy Between Animal and Plant Life.—M. van der Harst, in Utrecht, has discovered in the common garden bean, when it begins to sprout, a ferment analagous to pepsin, which can be extracted by means of glycerine. It has the power of changing albuminous into peptonic substances, and starch into glucose. It is found exclusively in the cotyledons. In the case of flesh-eating plants, all the steps of digestion seem to take place in the same manner as in animals.—*Fortsch. der Zeit.* C.

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STEAM-BOILER EXPERIMENT.

By Chief Engineer ISHERWOOD, U. S. Navy.

Table containing the Data and Results of an Experiment made in January, 1879, by a Board of United States Naval Engineers on the two Boilers of the Locomotive type in the machine-shop of the New York Navy Yard, to determine their economic Vaporization of Water by Anthracite.

		Duration of the Experiment, in hours and minutes,	21·45
TOTAL QUANTITIES.		Total number of cubic feet of feed-water vaporized, as measured in tank,	865·0000
		Total number of pounds of feed-water vaporized,	53964·2369
		Total number of pounds of anthracite consumed,	6820·0000
		Total number of pounds of clinker from the anthracite,	277·0000
		Total number of pounds of ash from the anthracite,	847·0000
		Total number of pounds of refuse from the anthracite, in clinker and ash,	1124·0000
		Total number of pounds of combustible, or gasifiable matter in the anthracite, consumed,	5696·0000
		Per centum of the anthracite in clinker,	4·0558
		Per centum of the anthracite in ash,	12·4193
		Per centum of the anthracite in refuse of clinker and ash,	16·4751
TEMPERATURES.		Temperature, in degrees Fahrenheit, of the external air,	30·6
		Temperature, in degrees Fahrenheit, of the air in the boiler-room,	71·6
		Temperature, in degrees Fahrenheit, of the feed-water in the tank,	42·5
		Temperature, in degrees Fahrenheit, of the feed-water when entering the boilers after passing through the heater,	175·0
		Temperature, in degrees Fahrenheit, of the gases of combustion in the uptakes of the boilers,	533·5
PRESSURES.		Height of the barometer, in inches of mercury, corrected for temperature,	29·54
		Steam pressure in the boilers, in pounds per square inch above the atmosphere,	35·47
		Steam pressure in the boilers, in pounds per square inch above zero,	49·97
		Pressure of the gases of combustion in the chimney below the atmospheric pressure, in inches of water, corrected for temperature,	0·16
RATE OF COMBUSTION.		Pounds of anthracite consumed per hour,	313·5632
		Pounds of combustible consumed per hour,	261·8851
		Pounds of anthracite consumed per hour per square foot of grate surface,	7·9049
		Pounds of combustible consumed per hour per square foot of grate surface,	6·6021
		Pounds of anthracite consumed per hour per square foot of heating surface,	0·5872
		Pounds of combustible consumed per hour per square foot of heating surface,	0·4904
VAPORIZATION.	*Total.*	Total number of pounds of feed-water that would have been vaporized, had its temperature when entering the boilers been 100 degrees Fahrenheit, and had the pressure upon it been equal to that of a mercurial column 29·92 inches high,	51241·3359
		Total number of pounds of feed-water that would have been vaporized, had its temperature when entering the boilers been 212 degrees Fahrenheit, and had the pressure upon it been equal to that of a mercurial column 29·92 inches high,	57228·4060
	Economic.	Pounds of water vaporized from 100 degrees Fahrenheit by one pound of anthracite,	7·5134
		Pounds of water vaporized from 100 degrees Fahrenheit by one pound of combustible,	8·9960
		Pounds of water vaporized from 212 degrees Fahrenheit by one pound of anthracite,	8·3913
		Pounds of water vaporized from 212 degrees Fahrenheit by one pound of combustible,	10·0471

TESTS OF A BALDWIN LOCOMOTIVE.

By John W. Hill, M. E.,
Member American Society of Civil Engineers.

Engine No. 36, of the Cincinnati, Hamilton & Dayton Railroad, is a Baldwin four-driver locomotive with 16 in. by 24 in. cylinders, and 61 in. diameter of drivers on the tread. The total weight of engine with two gauges of water, as weighed for trial, was 72,220 pounds, of which 44,800 pounds was carried by the drivers. The weight of tank, void of water and coal, as weighed for trial, was 23,480 pounds, and with coal and water, at Cincinnati (commencement of run), 47,398·36 pounds.

At Hamilton (first stop) the tank weighed 32,075·04 pounds, showing an expenditure, during the run, of 15,323·32 pounds, coal and water; of this 13,508·36 pounds was water, and 1814·96 pounds coal.

Upon leaving Hamilton, the weight of tank, coal and water was 45,583·40 pounds, and at Twin Creek (second stop) 35,150·08 pounds, showing an expenditure, during the run, of coal and water, 10,433·32 pounds; of which 8618·36 pounds was water and 1814·96 pounds coal.

Upon leaving Twin Creek, the gross weight of tank was 42,880·08 pounds, and at Dayton (third stop) was 31,755·38 pounds, showing an expenditure of coal and water of 11,124·7 pounds, of which 9650 pounds was water and 1474·7 pounds was coal.

The average dead load of engine and tender from Cincinnati to Hamilton was $72{,}220 + \frac{47{,}398{\cdot}36 + 32{,}075{\cdot}04}{2} = 111{,}956{\cdot}7$ pounds; from Hamilton to Twin Creek the average dead load of engine and tender was $72{,}220 + \frac{45{,}583{\cdot}4 + 35{,}150{\cdot}08}{2} = 112{,}586{\cdot}74$ pounds, and from Twin Creek to Dayton the average dead load of engine and tender was $72{,}220 + \frac{42{,}880{\cdot}08 + 31{,}755{\cdot}38}{2} = 109{,}537{\cdot}73$ pounds.

The distance from Cincinnati to Hamilton, as run, was 24·7 miles, from Hamilton to Twin Creek 15·87 miles, and from Twin Creek to

Dayton 17·09 miles, and the average dead load of engine, tender, coal and water for whole run was 111,413·33 pounds.

The resistance was obtained by a train of thirty-five loaded box freight cars and caboose weighing 1,454,470 pounds, making average gross load from Cincinnati to Dayton 1,565,583·33 pounds or 782·942 tons of 2000 pounds.

The engine is used in hauling express freight, and occasionally in hauling express passenger trains between Cincinnati and Dayton, and had been out of the shop twenty-two months. At time of test the engine had a record of 55,471 miles, and excepting the caulking of a seam in the waist of the boiler, and the setting up of the brasses in the rods, was run without any attempt to improve its condition. Of course it would not be held that the engine was tested under as favorable circumstances as though it were just from the shop or had run but a month or so on light traffic. The test, however, was not to ascertain what locomotive engines and boilers do under favorable conditions, but what they do under average conditions.

The Company owns engines of nearly every popular make, but as the "Baldwin" is probably the representative American locomotive, and is well-known in every part of the world where railroads prevail, one of these was selected for the experiments as being capable of more completely reflecting American locomotive practice.

It is to be regretted that so little test data exist upon the performance of American locomotive boilers and engines. The English and French engineers have given no inconsiderable attention to the economy of locomotive engines, whilst in this country the tests are few, and so far as the writer is aware no tests, excepting those herein detailed, have been made covering the connected performance of boiler and engines.

In the present instance much of the apparatus for the experiments was hastily improvised, and being limited to a given time in making the run from Cincinnati to Dayton, no opportunity was offered for a preliminary test by way of proving the correctness of the arrangements; with the exception, however, of the breaking of the speed counter after fifteen miles had been run, and the failure of the observer having charge of the calorimeter to note certain necessary data, the experiments were entirely satisfactory. The objects of the test were to ascertain

First. The economy of performance of the boiler.

Second. The evaporation capacity of boiler.

Third. Relation of heating surface to power developed by connected engines.

Fourth. Relation of grate to coal burned.

Fifth. The economy of performance of the engines independently considered.

Sixth. Relation of power developed to load.

Seventh. Power expended in moving engine alone at given speed.

The coal burned during the run was Pittsburgh No. 2, broken and screened; of this 6960 pounds was stored in the forward part of the tank, the hold having been divided transversely, forward of the centre, by a partition.

Upon both sides of the tank, at midlength, glass gauges were connected to furnish the water levels; the gauges were set centrally as regards the length of tank to furnish correct mean readings on grades, and two gauges were used to compensate for the elevation of one side of the tank in passing curves. The zero points of the scales attached to the gauges were made to coincide when tank was on a carefully leveled portion of the track in the Cincinnati yard; and the mean of the readings of the two gauges was held to represent the level of water on vertical axis of tank. Previous to the commencement and at the end of each run, sufficient time was allowed to permit the water to become entirely quiescent, when the levels were read and entered in the log. It was the intention to note the rate of consumption of water at intervals during the runs, but the violent and rapid oscillations of the water in the glass tubes rendered this next to impossible, and the readings that were taken are abandoned.

The temperature of the feed water in the tank was read every two minutes during the runs. After the tests were completed the tank was filled to highest gauge-point noted in the water log, weighed and the water drawn down to the next gauge point, re-weighed and so on until the least level of water noted in the log was reached; the temperature being noted, the weights thus obtained as quantities due differences of level in the tank were corrected to correspond with mean observed temperatures of water during the runs. No steam was blown into the feed pipes to heat the water during the tests.

The engines were precisely of the same dimensions except in the piston rods; that of the left engine having been renewed previous to the tests, and increased ·0625 in. in diameter. The diameters of cylinders and strokes of pistons, areas of steam and exhaust passages, travels and laps of valves, valve functions as measured on the guides, and, of course, the revolutions of both engines were the same; and, without data to the contrary, one would suppose that the load was equally divided between the two engines. To determine whether the engines did equal portions of the work, each was separately indicated. One indicator was attached to each cylinder; this was set forward of the mid-length and vertically over the steam chest; both ends of cylinder were piped to the indicator; the pipes from forward end and from the after end were of same dimensions of bore and length. An open-way stop-cock with lever handle was set in each branch of the indicator pipes to cut off the opposite end of cylinder when taking the diagram, and to shut off both ends when indicator was out of use. The pipes were necessarily of short lengths, and were carefully rounded at the ends and filed for whole length to offer as little resistance as possible to the flow of steam.

The indicator springs were made for the experiments by the Buckeye Engine Company, of Salem, Ohio, and were very accurate as developed by direct load test and precisely alike in their action. The diagrams were taken on the left engine by the writer, and on the right engine by an experienced assistant, and were taken simultaneously first from forward, then from back end of cylinder, from signals given on the engine's whistle. The diagrams were taken every two minutes during the run, except at times when engine was on down grade and steam shut off. Excepting certain diagrams, to which attention is directed, all were taken with throttle wide open and speed of engines controlled by the links and reversing lever. In addition to the operators at the indicators, two assistants rode on the pilot of the locomotive and noted on the diagrams the consecutive numbers and engines (right and left) from which they were taken.

From Cincinnati to Hamilton water tank, a distance of 24·695 miles, the run was made in one hour and twenty-six minutes, during which time were taken forty diagrams from each end of each cylinder, or eighty cards from each engine. From Hamilton to Twin Creek, a distance of 15·869 miles, the run was made in forty-two minutes, during which time were taken twenty diagrams from each end of each cylinder or forty cards from each engine. From Twin Creek to Dayton, a distance of 16·267 miles, the run was made in 42·5 minutes, during which time were taken twenty-one diagrams from each end of each cylinder or forty-two cards from each engine; making three hundred and twenty-four diagrams in a total run of fifty-seven miles, or an average of nearly six diagrams (both engines) per mile run.

The track in plane is composed of a succession of curves and tangents. From Cincinnati to Dayton the road was divided into ninety-six stations, each station indicating the southern end of the curve, simple or compound, or tangent as the case might be. From profiles of the road-bed and the civil engineer's notes, a chart was prepared showing the succession of the stations, grades and levels, distances from station to station measured in the centre of track, angular deflection of curves, degrees comprised in the arcs, and ratio of ascending or descending grades. An observer sat at the right cab window and noted the time, to second, of passing each station.

A calorimeter consisting of a coil of brass drawn tube and a tin tank, the whole arranged as a small surface-condenser, was used to obtain the data from which to estimate the quality of steam produced; the upper end of coil, which was set vertically in the tank, was connected by a small pipe with the after steam-dome, and an open way cock, with an orifice ·0469 in. diameter, controlled the flow of steam to the coil; the lower end of the coil was carried through the side of the tank and turned down into a receiving tank, where the water of condensation was collected. The condensing water was carried in a saddle-tank, set on the boiler between the forward dome and sand box, a rubber hose conveying the water into the condenser. The injection entered at the bottom of the condenser and passed out at the top, a rubber hose carried out on the running board delivering the hot condensing water clear of the track. Three temperatures were read—the injection, overflow and condensation from the worm; and two quantities were noted—the expense of condensing water in the saddle-tank and weight of condensation from the worm.

Although the arrangements for taking the calorimeter observations were very complete, the record at this point is useless; the assistant having entirely overlooked the observations of condensing water expended.*

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* The writer would suggest that whilst it is an easy matter in directing experiments on stationary, marine or pumping engines, to visit and confer with the assistants and verify or correct their records during the tests, this is impossible in making a running

The boiler pressures were taken from a steam-gauge made for the experiments, and by mercury column, practically accurate; a speed-counter, taking motion from the swinging arm attached to the cross-head of the left engine to drive the indicator, was secured on the after end of cab.

The writer was extremely anxious to obtain a correct record of the revolutions of drivers; to arrive at the imperceptible slip, the exact running distances were carefully measured by the civil engineer of the road subsequent to the tests, as also the running times during the tests, and with a correct record of the revolutions, the imperceptible slip of driver for whole runs and increments of runs could have been obtained with great precision. The counter record, however, covers only the first sixteen miles of the run from Cincinnati to Hamilton. The time was taken from a lever clock in the cab of the engine, and the signals were given regularly every two minutes on the whistle. Fifteen seconds previous to each reading, two short blows were given to notify the observers of an approaching observation, and upon completion of each two-minute interval a single sharp blow produced a simultaneous action of the assistants.

It has been intimated that test data on the performance of American locomotive engines are scarce. The master mechanics of the various railroads assemble in convention once each year, and discuss a list of topics pertinent to locomotive practice from an experimental standpoint, and, singular as it may seem, two master mechanics in different parts of the country, will test the same improvements under the same conditions, and obtain diametrically opposite results, one lauding the improvement as a magnificent success, and his opponent condemning it as a miserable failure. (*Vide* "Annual Reports of the Master Mechanics' Association.")

Of course such experiments as these are worthless, and the sooner locomotive builders and railway companies learn to test by systematic methods the machinery built by the one and used by the other, the sooner will locomotive practice appreciate that of the marine, pumping and automatic cut-off engines.

Whenever railway companies are taught to buy locomotives as municipal corporations buy pumping engines, and steamship compa-

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test of a locomotive, each observer being practically glued to his station, and unless fully cognizant of and familiar with his duties, is very liable to error in making up his notes.

nies buy marine machinery, then and not earlier will the economic and capacity value of the locomotive engine advance.

The writer must not be understood as denying excellence in the American locomotive; upon the contrary, that excellence is fairly proven by these experiments; but while these experiments are convincing as to the merits of the "Baldwin" engine, they do not show the precise position of the engine in the scale of merit. The Baldwin is generally recognized as the representative American locomotive; and certainly, if enterprise and liberality is a gauge of merit, then the Baldwin Company is entitled to the palm; but, independent of any general impressions that may prevail in behalf of the Baldwin, the Rogers, or the Grant locomotive, it is to the interests of the builders of these engines to place their machinery before railway companies, not upon the opinion of any or all master mechanics, but upon a foundation of facts, and these facts to be obtained by methods that leave no room to doubt the pronounced value of the machine.

There was a period in the history of American railways when the economic and capacity value of a locomotive was of very little moment. If one engine was incapable of hauling a load between given points in a given time, the load was divided, and two engines and two sets of men were employed to do the work. If the expense of fuel to overcome a given resistance in a given time was twice what it should have been, no interest was felt in reducing it, as fuel was cheap and dividends large. This, however, is not the condition of American railways at present; few companies can profitably neglect the cost of operating their locomotives, and whilst (so far as the writer is aware) no intelligent effort has been made by any railway company to materially advance the economic and capacity standard of their engines, the desire to do so is manifested quite the same.

Unfortunately railway managers are rarely qualified to examine and criticise the precise performance of locomotives, and are compelled to rely entirely upon their master mechanics to fill the position of an expert as well as a superintendent of machinery. From an extensive acquaintance among the steam engineers of this country, the writer has yet to discover the superintendent and expert successfully embodied in the same person; and experience has shown that he who is eminently successful as a superintendent of men is very unlikely to develop extraordinary talent as an expert.

Without adverting further to the "eternal fitness of things," in the operation and development of the American locomotive engine, the writer would suggest that the test of a Baldwin engine has for its object the creation of a deeper interest upon the part of locomotive builders and railway companies in this eminently useful machine.

In the following tables are given the dimensions of boiler and engines, from data furnished by Mr. James Eckford, master mechanic of the road. The clearance was determined by setting the engine on the centre and waxing the piston to prevent transfer of water from clearance to opposite end of cylinder. The cylinder head was then replaced and the void filled with water to level of valve seat. The water was then drawn off by the drain-cock, weighed and temperature noted. The volume of clearance thus obtained was slightly in excess of that measured on the drawings from which the engine was built, but this is easily accounted for by a discrepancy between the drawings and patterns. The throttle was of the poppet double beat type, the upper annular area alone being effective. The driving wheels were originally 60″ diameter, but by "retiring" were increased to 61″.

The weight on the drivers was obtained by backing the engine, disconnected from the tank, on the scale and noting the load. The engine was then run on the scale and gross weight taken.

DIMENSIONS OF BOILER.

Fire-box, length inside,	ins.	63·00
" height, "	"	60·50
" width, "	"	34·50
Barrel, length,	"	128·50
" diameter,	"	48·00
Smoke-box, length,	"	33·50
Tubes, length,	"	132·00
" diameter (outside),	"	2·00
" number,		138.
Heating surface in fire-box,	sup. ft.	93·85
" tubes,	"	794·82
" front tube sheet,	"	10·00
" aggregate,	"	898·67
Cross section of tubes (calorimeter),	sup. in.	346·36
" chimney,	"	254·47
Area fire-grate,	sup. ft.	15·09
Ratio of heating to grate surface,		59·647

Ratio of grate surface to calorimeter,	6·27
“ calorimeter to chimney,	1·36
Steam domes, number,	2.
“ diam. (inside),	ins. 23·50
“ height,	“ 28·00
Supply dome, center of barrel,	
Rear “ “ fire-box,	

DIMENSIONS OF ENGINES.

Number of cylinders,	2.
Diam. “	ins. 16·0000
Stroke of pistons,	“ 24·0000
Diam. of piston rod (right),	“ 2·7500
“ “ (left),	“ 2·8125
Effective mean area of piston (right),	“ 198·0900
“ “ “ (left),	“ 197·9100
Clearance in parts of stroke,	·0760
Increase in stroke due clearance,	“ 1·8240
Area of openings through throttle,	“ 12·6646
“ steam pipe (15″ × 1·25″),	“ 17·2000
“ “ ports (15″ × 2·50″),	“ 18·7000
“ exhaust “	“ 37·4000
“ “ nozzles,	“ 5·9400
Travel of slide valves in full gear,	“ 5·3125
Steam lap on slide valves,	“ ·8750
Exhaust lap “	“ ·0625
Diam. of drivers (four),	“ 61·0000
Driving wheel base,	ft. 8·0000
Total, “ “	“ 22·0000
Weight on drivers,	pds. 44,840
“ of engine (total) with two gauges of water.	“ 72,220

In the following tables of boiler and engine performance, the runs from Cincinnati to Hamilton, from Hamilton to Twin Creek and from Twin Creek to Dayton are separately considered.

As the boiler is the source of the power, or more correctly speaking, the fuel burned in the furnace is the source of the power, and the boiler the means of adapting the calorific effect of the fuel to useful work, the first inquiry will be into the performance of the boiler.

The run from Cincinnati to Hamilton occupied one hour and twenty-six minutes, without stop, during which time there was pumped into the boiler 13,508·36 pounds of water as against 1814·96 pounds of coal. By the English method of estimating boiler efficiency, it is assumed that the water fed to the boiler represents the total evaporation, but from numerous experiments by the writer and others on boiler performance, the fact has been established that, except superheating surface be provided, no boiler furnishes *saturated* steam. So far as the writer is aware, locomotive boilers are not provided with superheating surface, and it is proper to assume that a certain percentage of the total water pumped into the boiler went into the dry pipe as liquid. The arrangements for taking the data upon which the primage would be estimated were very complete, but the negligence of the assistant charged with the work of observation defeated this part of the test. The relatively large heating surface to water carried, excellent circulation, and high temperature of waste gases are all calculated to reduce the primage to a minimum; the primage is taken at *five per cent.* for each run; hence saturated steam furnished during first run was 12,832·94 pounds, and steam per pound of coal 7·0706 pounds, or estimated from and at 212° Fahr. 8·36 pounds. Estimating the coal blown unconsumed out of the chimney by the blast, at five per cent. and efficiency of coal as ninety per cent. an equal weight of carbon, then evaporation from and at 212° Fahrenheit was $\frac{8{\cdot}36}{{\cdot}855} = 9{\cdot}77$ pounds.

Mr. D. K. Clark, in his "Manual for Mechanical Engineers"* furnishes a table of the performance of sixty-one locomotive boilers, fifteen of which exhibit an evaporation in excess of *ten pounds* per pound of coke, estimated from and at 212° Fahr. The manner in which the boilers were tested, pressure of evaporation, speed, load, grades and efficiency of coke are either unknown or carefully omitted. All these elements have a decided bearing on the evaporation performance of a locomotive boiler, and it would be manifestly unfair to compare the performance of the "Baldwin" boiler with that of any other make unless both were worked under similar or known conditions. It is not known that any special differences in design and construction exists between the standard locomotive boilers of America and England, and with equal efficiency of fuel and like conditions of performance, the evaporation for boilers of similar dimensions should be approximately the same whether tested in this country or the other. The "Baldwin" boiler was not tested to obtain maximum results, but to obtain results under ordinary conditions of performance, and in the writer's opinion, the economy, as shown during the run from Cincinnati to Hamilton, is excellent.

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* Pp. 799–800.

The capacity of the boiler, during this run, in steam per hour, from and at 212° Fahr., was 10,586 pounds of steam per hour or nearly *ten pounds* actual evaporation per square foot of heating surface. It is customary to estimate the capacity of a tubular boiler with natural draft, at fifteen square feet of heating surface per horse-power of effect of connected slide-valve engine, but in this run 3·243 square feet of heating surface were required per horse-power of connected engine. The slide-valves of the engines were worked by links, but the cut-off was in round numbers half stroke, and the difference between the capacity with natural draft and as developed during the run, is due to the effect of blast. The engines developed unusual economy, as will be shown, and assuming the expense of steam per horse-power per hour at *forty-five* pounds, then the heating surface per horse-power of connected engines becomes *four and one-half* square feet, and the rate of effect of boiler with blast to effect of boiler with natural draft is

$$\frac{15 \times 32 \cdot 3}{3 \cdot 243 \times 45} = 3 \cdot 32.$$

With natural draft, the expense of coal per hour per square foot of grate would have been about twenty-five pounds, and during the run the rate of consumption of coal referred to area of grate was eighty-four pounds; hence ratio of effect with blast to effect with natural draft becomes

$$\frac{84}{25} = 3 \cdot 36.$$

The run from Hamilton to Twin Creek occupied *forty-two* minutes, during which time 8618·36 pounds of water were pumped into the boiler and 1814·96 pounds of coal were fired on the grate. Estimating primage, as before, at five per cent., the saturated steam furnished during this run was 8187·44 pounds. The evaporation per pound of coal was 4·5 pounds, or from and at 212° Fahr., 5·34 pounds; but the capacity of the boiler from and at 212° Fahr. was at the rate of nearly

14,000 pounds of steam per hour, or 13 pounds of steam per square foot of heating surface per hour. During this run the expense of steam per hour per horse-power of connected engines (based on total saturated steam furnished) was 33·4 pounds, and heating surface per horse power developed $\frac{33{\cdot}4}{13} = 2{\cdot}57$ square feet.

Estimating, as before, with natural draft, *fifteen* square feet of heating surface per horse-power of effect of connected engine, and *forty-five* pounds as the expense of steam per hour per horse-power developed by engines, then the ratio of effect of blast to effect of natural draft is

$$\frac{15 \times 33{\cdot}4}{2{\cdot}57 \times 45} = 4{\cdot}332$$

and, as before, estimating consumption of coal per square foot of grate per hour with natural draft at twenty-five pounds, then the ratio of effect of blast to effect of natural draft is with a consumption of 172 pounds of coal per square foot of grate per hour as during the run:

$$\frac{172}{25} = 7 \text{ nearly.}$$

In the run from Cincinnati to Hamilton it has been shown that the ratios of effect of blast to effect of natural draft; by heating surface per horse-power of connected engines, and by coal burned per sq. ft. of grate per hour, were approximately the same; whilst in the run from Hamilton to Twin Creek the ratio by coal burned is nearly sixty-five per cent. in excess of ratio by heating surface. Neglecting the loss of heat by extra radiation during the run, which was very small, and assuming the consumption of fuel per sq. ft. of grate to vary directly as the blast, and the blast to vary directly as the weight of steam exhausted per second, then the consumption of coal per sq. ft. of grate per hour for second run becomes 120·75 pds. and the ratio of effect of blast to effect of natural draught as measured by the coal burned is

$$\frac{110{\cdot}86}{25} = 4{\cdot}434$$

The economy of performance of the boiler, or the evaporation per pound of coal charged to the furnace, was very low during the run; but the economy is based on the total coal charged, with no allowance for that blown unconsumed out of the chimney.

According to Mr. Longridge,* "the rate of combustion has no influence on the economic effect," and this is probably true, if the evaporation is referred to the coal actually burned to carbonic acid; but assuming in the run from Hamilton to Twin Creek a combustion equivalent to that of run from Cincinnati to Hamilton, then the evaporation from and at 212° Fahr. becomes 7·6 pds. per pound of coal as compared with 8·36 pds. for previous run.

The run from Twin Creek to Dayton occupied *fifty minutes*, during which time the water pumped into the boiler was 9650 pds. and coal fired 1474·7 pds. Estimating primage, as before, at *five per cent.*, the saturated steam furnished was 9167·5 pds., or an actual evaporation of 6·216 pds. per pound of coal. Equivalent evaporation from and at 212° Fahr., 7·3 pds. The coal burned per sq. ft. of grate per hour was 117·27 pds., and capacity of boiler in steam per hour from and at 212° Fahr., 12918 pds., or actual evaporation per sq. ft. of heating surface per hour, 12·24.

The expense of steam per hour per horse-power of connected engines during the run was 33 pounds (based on total steam furnished) and heating surface per horse-power of effect of engines,

$$\frac{32}{12{\cdot}24} = 2{\cdot}614$$

Estimating with natural draft *fifteen* sq. ft. of heating surface per horse-power of effect of connected engine, and *forty-five* pounds of water per hour per horse-power, then the ratio of effect of blast to effect of natural draft is $\frac{15 \times 32}{2{\cdot}614 \times 45} = 4{\cdot}08$

Estimating the coal burned per sq. ft. of grate with natural draft at 25 pds., then ratio of effect with blast to effect with natural draft, with a consumption of 117 pounds of coal per sq. ft. of grate per hour

$$\frac{117}{25} = 4{\cdot}68$$

Upon the assumption that the coal burned per sq. ft. of grate should be directly as the effect of blast the ratio of effect by blast to effect by natural draft during run from Twin Creek to Hamiton was

$$\frac{101{\cdot}02}{25} = 4{\cdot}041$$

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* Proceedings Inst. C. E., vol. iii, Session 1877–78, part ii, page 17.

Heating surface per horse-power and ratio of effect of blast.

Run.	Heating surface per H. P. sq. ft.	Ratio of effect of blast to natural draft by coal burned.	Ratio of effect of blast to natural draft by heating surface
Cincinnati to Hamilton,	3·243	3·36	3·32
Hamilton to Twin Creek,	2·57	4·434	4·332
Twin Creek to Dayton,	2·614	4·041	4·08

Assuming a combustion during the run from Twin Creek to Dayton equivalent to that from Cincinnati to Hamilton, the evaporation per pound of coal from and at 212° Fahr. during former run is

$$\frac{7·3 \times 117·3}{101·02} = 8·476 \text{ pds.}$$

And the evaporation for equivalent combustion for the several runs becomes

Cincinnati to Hamilton, . . .	8·36 pds.
Hamilton to Twin Creek, . .	7·60 "
Twin Creek to Dayton, . . .	8·476 "

Upon examination of the following table of boiler performance, it will be observed that the rate of consumption of coal per hour during the second run was 172 pds. per sq. ft. of grate. Of the fifty-two locomotive boilers, the performance of which are reported by Mr. D. K. Clark, the highest rate of combustion is 157 pds. of coke per sq. ft. of grate. Of the 172 pds. of coal charged per foot of grate, not less than *twenty per cent.* must have been blown unconsumed out of the stack. For the conditions of load, speed, pressure of evaporation, steam per indicated horse-power, grades, quality of coal and effect of blast were quite the same for the second and third runs, and the theoretical evaporation during the third run was superior to the first run. There were no material differences between the data for the second and third runs, and the evaporation should have been approximately the same. But the evaporation during the second run was nearly *twenty-seven* per cent. below that of the third run, and this excessive discrepancy can only be accounted for by assuming that a large proportion of the coal charged on the grate left the furnace unconsumed. The facility with which a locomotive boiler operating under a strong blast can distribute unburnt coal along the track is well known, but it is doubtful if the percentage of coal thus disposed of is equally well known.

Under the ordinary conditions of locomotive performance, with careful firing and regular blast, the loss of coal by this avenue is, in the writer's opinion, rarely less than *five per cent.*

Taking the run from Cincinnati to Dayton as a whole, the average evaporation per square foot of heating surface was 11·740 pounds per hour. According to Mr. Harvey "the evaporation per unit of recipient surface decreases in geometrical progression, whilst the distances from the commencement of the series of such surfaces increases in arithmetical progression," but this law of evaporation only holds good "at points where the radiation of heat from the fuel ceases and communication of heat by conduction begins," in other words the law only applies to evaporation by the tube surfaces alone, and has no bearing upon the evaporation by fire-box surface. From the experiments of M. Pétiet on one of the locomotives of the Northern Railway of France, where the fire-box surface was 60·28 square feet and the tube surface 732·15 square feet, the fire-box surface furnished nearly sixty per cent. of the total evaporation. The manner, however, in which M. Pétiet's experiments were made, precluded the possibility of good circulation, such as obtains in a locomotive boiler under ordinary working conditions, and the results cannot be used as a basis of estimate for the evaporation by fire-box and the tube surface, when the circulation is good. It is assumed, however, that of the total evaporation as in M. Pétiet's experiments, sixty per cent. was due the fire-box surface, and that the evaporation in two boilers would vary distinctly as the relative surface in the fire-boxes. The ratio of fire-box to total heating surface in the French experiments was $\frac{60·28}{810·43} = ·0753$, and for this trial $\frac{93·85}{898·67} = ·1044$ and $\frac{·1044 \times ·60}{·0753} = ·832$, and the evaporation per square foot of fire box surface becomes $\frac{10,550 \times ·832}{93·85} = 93·53$ pounds.

Upon this estimate, each sup. foot of fire-box surface furnished nearly *one hundred* pounds evaporation per hour. It should be borne in mind that the feed is usually introduced cold into the forward end of a locomotive boiler, and that the tube surface is given to the first heating of the water, and it is probable that by the time the water, by circulation, reaches the fire-box it has been furnished with nearly, if not quite all, the sensible heat due steam at the pressure of evaporation.

If this proposition be true, then each pound of steam made by the fire-box surfaces contained 866·21 thermal units, and the heat transmitted per sup. foot of fire-box surface was

$$866·21 \times 93·53 = 81,016·62$$

thermal units.

Mr. Longridge, in an elaborate paper read before the Institution of Civil Engineers, London, on the evaporation power of locomotive boilers, quotes from experiments by M. Paul Havrez, the maximum rate of transmission through a superficial foot of fire-box surface with coal, as 40,590 units of heat per hour; less than fifty per cent. of the rate of transmission by the "Baldwin" fire-box after crediting the tube surface with the elevation of the feed water from the temperature at which it was introduced to that of the evaporation.

This rate of transmission, however, is based upon an assumption that may not be true, and as against the *fire-box* furnishing over eighty per cent. of the total evaporation, Mr. Longridge arrives at the conclusion that the *tube surface* furnishes nearly eighty per cent. of the evaporation. Upon the other hand M. Pètiet finds from experiment that *sixty per cent.* of the evaporation is due the fire-box and *forty per cent.* due the tubes, and in his experiments the relation of the total fire-box surface to the total heating surface was as 1 to 13·3 nearly, whilst the ratio of the fire-box surface to the total surface with the "Baldwin" boiler was as 1 to 9·6 nearly. The writer is of the opinion that the relative efficiency of fire-box surface is directly as the ratio of tubes to fire-box surface, and that the evaporation, 83·3 per cent., credited to thefire-box in the "Baldwin" boiler is too great. From experiments by the Count De Pambour and Mr. E. Woods on a locomotive boiler with natural draft, it was found that "the fire-box surface did twenty times the duty of the tube surface, but by varying the conditions and increasing the draft artificially the ratio instead of being 1 to 20 became 1 to 7½." Whether this is a comparison of the work of the fire-box with the tube surface, taken as a whole, or for equal areas of surface is not stated by Mr. Woods, but from the tenor of the gentleman's remarks it is inferred that the former comparison is made.

There are certain very desirable data in connection with locomotive boiler performance that were not obtained during these trials: the temperature of fire and temperature of waste gases; velocity of flow through the flues; of products of combustion, air introduced per pound of combustible; and composition of the gases in the stack.

Before dismissing the performance of boiler, the writer would suggest that trials of locomotive boilers of different kinds are now in projection, during which trials all data necessary to estimate the precise action will be taken.

PERFORMANCE OF THE BOILER.

Cincinnati to Hamilton.

July 28th, 1878.

Duration of run,		1 hr. 26 min.
Mean temperature of air,		98·31
“ “ feed-water,		78·535
“ “ evaporation,		350·
“ pressure above atmosphere,	pds.	120·381
Water pumped into the boiler,	“	13508·36
“ primed, estimated 5 per cent.,		675·42
Net steam furnished,	“	12832·94
Coal burned,	“	1814·96
Steam actually furnished per pound of coal,	“	7·0706
Equivalent evaporation from and at 212°,	“	8·360
Evaporation per sup. ft. of heating surface per hour, actual,	“	9·963
Evaporation per sup. foot of grate surface per hour,	“	593·316
Coal burned per sup. foot of grate surface per hour,	“	83·913
Evaporation from and at 212° per hour,	“	10585·85

Hamilton to Twin Creek.

Duration of run,		42 min.
Mean temperature of air,		88·45
“ “ feed-water,		77·05
“ “ evaporation,		352·00
“ pressure above atmosphere,	pds.	124·443
Water pumped into boiler,	“	8618·36
“ primed, estimated 5 per cent.,	“	430·92
Net steam furnished,	“	8187·44
Coal burned,	“	1814·96
Steam actually furnished per pound of coal,	“	4·511
Equivalent evaporation from and at 212°,	“	5·344
Evaporation per sup. ft. of heating surface per hour, actual,	“	13·015

Evaporation per sup. foot of grate surface per hour,	“	775·106
Coal burned “ “ “	“	171·822
Evaporation from and at 212° per hour,	“	13855·92

Twin Creek to Dayton.

Duration of run,		50 min.
Mean temperature of air,		92·130
“ “ feed-water,		86·326
“ “ evaporation,		349·380
“ pressure above atmosphere,	pds.	119·610
Water pumped into the boiler,	“	9650·
“ primed, estimated 5 per cent.,	“	482·50
Net steam furnished,	“	9167·50
Coal burned,	“	1474·700
Steam actually furnished per pound of coal,	“	6·216
Equivalent evaporation from and at 212°,	“	7·300
Evaporation per sup. ft. of heating surface per hour, actual,	“	12·241
Evaporation per sup. foot of grate surface per hour,	“	729·025
Coal burned “ “ “	“	117·272
Evaporation from and at 212° per hour,	“	12918·37

(To be continued.)

THE BUTLER MINE FIRE CUT-OFF.

By Henry S. Drinker, E. M., Philadelphia.

(Read at the Lake George Meeting of the American Institute of Mining Engineers, October, 1878.)

The Butler Mine property is situated in the vicinity of Pittston, in the Wyoming coal-field of Pennsylvania. The coal has been worked out from the fourteen-foot or Baltimore vein for a number of years on part of the tract, the old chambers remaining open as when originally abandoned. This vein outcrops on the Butler property, and is nowhere more than sixty feet below the surface of the ground on the line of the cut-off to be described. Above the fourteen-foot vein and about, say midway, between it and the surface of the ground, there is another small vein or rider of coal, about twelve inches in thickness. The rock between the two veins is a corbonaceous slate, about twenty-five feet in thickness. Above the smaller vein is a bed of sandstone, varying in thickness, but generally not less than from eight to ten feet. This sandstone is also carbonaceous, but the proportion of carbon is much less than in the slate below. Both rocks have been analyzed, and before the next Institute meeting the writer hopes to be able to furnish the exact proportions. The sandstone is overlaid with *débris* up to the surface of the ground.

Some time during the spring of 1876 it was found that the coal left in the worked-out mine had been set on fire, and that the fire was gradually spreading. Inquiry developed the fact that the fire had originally been started by a woman, who had taken up her abode in an old tunnel leading into the workings. Owing to some delay in the early attempts made to extinguish the fire, it finally gained such headway that no ordinary means were found to be effectual. Finally, Mr. C. F. Conrad, civil and mining engineer, of Pittston, Penna., was called in as consulting engineer. He advised the making of a thorough cut through such portion of the old workings as had not been reached by the fire. It was found by survey that this cut could be limited to a length of about one thousand two hundred feet, as the vein faulted on both sides, and that the greatest depth of the cut would be about sixty feet. Subsequently it was decided to tunnel part of the way, thus saving the deepest portion of the cut.

In 1856–7 there occurred a fire in the same mine. Two stone walls in V shape, running from the apex of the V towards the out-crop, were built to cut the fire off, and these walls were carried as far as the vein had at that time been worked. After the walls were finished the old workings were filled in on both sides with clay and sand, making the spaces air-tight; this helped to stay the fire; it, however, finally broke through to the surface of the ground, and only went out when it reached the solid coal.

The present cut passes through the point of junction of the old V walls, and is, therefore, located directly through the *débris* and ash of the old fire. This location for the cut-off was decided on by Mr. Conrad, after a careful survey, for two reasons. 1st. In the hope of finding all combustible matter, coal, gob, carbonaceous slate, etc., burnt to ash by the old fire. In this case much excavation would be saved, as the ashes of an extinct fire might fairly be assumed to be an impassable barrier to a new one, and 2d. In the hope that if the material were not found to be fully calcined, still that its burnt condition would render it more workable, and thus more easily removed.

After removing the surface material the walls above described were found, and then about twenty-five feet beyond them a solid pillar of coal in place. Where this opening was thus first made to the old fire, the covering over the vein was from thirty to thirty-five feet thick, about three to five feet of surface soil and earth, and the remainder yellow slaty sandstone and coal slate, the slate and the sandstone being parted by the rider or small coal vein above noted. It was at this point that a curious fact was developed, and it is in order to bring it to the attention of the Institute that the writer has prepared the present communication. On investigation, it was proved that the old fire had not penetrated the solid coal *in place.* Where it met a pillar in the workings, the coal was simply calcined on its surface; but in all cases *the overlying slate rock was calcined throughout.* Nay more, for the 14-foot vein on the Butler property is nearly equally divided by an 8-inch parting of slate, and it was found that this slate rock (with sound, bright coal on both sides), had been thoroughly calcined. Above the 14-foot vein the rock was also found to be calcined up to and above the 12-inch rider, or small vein, while this small vein of solid coal was also found to be unburned and perfectly sound and bright, as in the case of the larger vein.

Finally, it was found on excavating further, that when the old fire had reached the face of the workings, its progress had been arrested.

From this experience it would appear to be established that coal *in situ cannot* be burned *en masse;* but that the walls of carbonaceous slaty rock inclosing solid coal *can* be burned or calcined *in situ.* On what theory this fact can be explained may be an interesting matter for discussion to some members of the Institute, more directly connected than the writer can claim to be with problems of this nature. At the February meeting (1879) the writer expects to be able to present samples of the coal and rock referred to, both in its calcined and in its natural state, and by that time he hopes also to have the analyses above referred to, showing the proportion of carbon in the slate and sandstone. It should also be stated here, that even the sandstone was found to be burned, though not so thoroughly as the slate.

At present the question to the company, of course, is, whether the new fire, now raging, will be stopped by the cut or not. The cut was made about 30 feet wide, and is carried from one end of the coal to the other, and down to the foot-wall of the vein. About 200 feet of the distance has been tunnelled. At this point the vein has been removed, and heavy walls built on either side of the tunnel. Also the adjacent old workings towards the fire have been filled with clay and incombustible *débris*, and it is believed by the engineer in charge that this, with the cut, will afford an effectual stay to the fire, which is expected to reach the line of the cut some time in January or February, 1879. When the present fire becomes extinct, it will be an interesting matter to note, whether in the old workings in which it has been raging, the pillar coal has remained unburned as in the old fire. That the superimposed slate and sandstone is being calcined is evident, for the craters formed over the surface show on all sides, at night, glowing masses of incandescent rock, extending often up to the surface.

The writer hopes to be able to supplement the present paper by another, at some subsequent meeting, giving a full account of the construction of the cut-off and of its result. This, of course, cannot be done until the fire has progressed farther, and actually reached the cut.

Since the original publication of Mr. Drinker's paper, above, in the Transactions of the American Institute of Mining Engineers, the fire described has been gradually nearing the cut, and at some points smoke has been observed coming into the side of the cut towards the fire. It is however, still too soon to state definitely whether the cut will have its desired effect in arresting the fire or not, or whether the fire may still travel across, over the tunnel, through the carbonaceous slates overlying it. The discussion of Mr. Drinker's paper by mining engineers seems to have established the general opinion, that the slates in the old fire were not actually burned, but that the carbonaceous matter in them was rather subjected to a process of distillation. It is said that some careful tests are about to be made on this point, by subjecting a quantity of the slate to a high heat under various conditions, and the results, together with some further notes on the Butler Mine, will be submitted to the Institute of Mining Engineers, at their next meeting, in May, at Pittsburgh.—ED. JOURNAL.

German Petroleum.—Near Heide, in Holstein, a flowing petroleum well has been bored which yields an oil of a quality similar to that of the American wells.—*Der Techniker.* C.

Atmospheric Impurities.—It is estimated that England yearly uses 114,043,940 tons of coal. If we suppose it to contain only one per cent. of sulphur, there is an annual infusion of 3,500,000 tons of sulphuric acid into the air, which the inhabitants are obliged to breathe. —*Der Techniker.* C.

Education in France.—France now has 253 colleges and 86 lyceums. Towards the end of the reign of Charles X. the educational budget amounted to but 1,825,000 francs, while the expenses of the royal family were 32,000,000 francs. Under the second empire the outlay for public instruction was raised to 3,000,000 francs. The republican administration increased the amount to 38,000,000 in 1876, 49,000,000 in 1877, and 57,000,000 in 1878. Of the last appropriation 30,000,000 francs were for elementary instruction.—*Der Techniker.* C.

Encouragement of Art.—In the eighteenth century the laws of Prussia required that every wealthy Jew who married should buy his porcelain at the royal manufactory in Berlin. The director often took the money and made his own selection of pieces to be given in exchange. Moses Mendelssohn, although celebrated as a philosophical thinker and writer, was obliged to submit to the law, and he received forty porcelain apes, of life size. Some of them are still preserved in the Mendelssohn family. This method of oppressing conscience for the development of ceramic art was established during the reign of Frederic the Great, the philosophical King.—*Archives Israélites.* C.

Electrodynamic Induction.—It is a common impression among electricians that a telegraphic conductor can be withdrawn from the inductive influence of neighboring conductors by metallic envelopes which are connected with the ground, but H. DeMauex tried some experiments in the month of February, 1878, preparatory to the establishment of the telegraphic service of the French Exposition, which led him to the discovery of a new law. In electrostatic action, the induction may be prevented by the proposed method, but the law relative to electrodynamic induction is thus stated: In a closed circuit the intensity of the current, which is determined by the induction of a cylindrical conductor upon another of the same form, cannot be changed even by surrounding one or both of those conductors by a concentric metallic envelope communicating with the ground through its entire length. —*Comptes Rendus.* C.

Dry Coating for Basement Walls.—Take fifty pounds pitch, thirty pounds resin, six pounds English red, and twelve pounds brick-dust. Boil these ingredients and mix them thoroughly; then add about one-fourth the volume of oil of turpentine, or enough to flow easily, so that a thin coating may be laid on with a whitewash or paint brush. Walls thus coated are proof against dampness.—*Der Techniker.* C.

Influence of Color on Warmth of Soil.—By an extensive series of experiments, E. Wollny shows that the color of the surface has an important influence on the heating of the ground in a dry condition, where the mineral constituents are substantially the same, and the difference in the quantity of humus is only such as to produce a difference of color, without changing the specific heat or conductivity.—*Dingler's Journal.* C.

Von Oppolzer's Planet.—The tenth orbital confirmation of Chase's harmonic astronomical prediction, represents the closest planetary proximity to the sun of which any indications have yet been found. There are six interior positions, but they are connected with planetary rotations. Von Oppolzer finds that his orbit accords very well with the three latest observations, which are the most important because the exact time of observation is known. It also satisfactorily represents five other observations. It is impossible to connect it with either of Watson's two planets. Lescarbault's observation being one of the three latest, this appears to be the *true* Vulcan, and other names must be found for its companions.—*Comptes Rendus.* C.

Telectroscope.—M. Senlecq, of Arles, has invented an apparatus for the telegraphic reproduction of images formed in the camera obscura. In the focus of the camera is a ground glass slide, with a selenium point in the electric circuit. As the point moves over the light or dark portions of the glass the selenium communicates, with great sensitiveness, the vibrations of light. The receiver is a soft plumbago or crayon point, attached to a very thin plate of soft iron, and vibrating before an electro-magnet, which is governed by the irregular current from the selenium. When the selenium passes over an illuminated portion, the current increases in intensity, the electro-magnet checks the vibrations and the crayon exerts less pressure on the paper. When the surface is dark, contrary results are produced and a well-shaded copy is thus made.—*Les Mondes.* C.

Digestion of Albuminoids in Invertebrates.—Dr. Leon Fredericq, of the University of Ghent, finds that the digestive mechanism is the same in all animals. The transformation of food is always effected by the mediation of substances like the digestive ferments of the vertebrates, and the products of digestion are uniform.—*Les Mondes.* C.

Chemical Volcano in Nebraska.—On the shores of the Missouri, in Dixon county, about 36 miles from Sioux City, there is a large bluff, a part of which fell into the river about two years ago. When the ear is applied to the ground, internal rumblings are heard, and flames occasionally appear, especially by night, steam issues from crevices and the neighborhood appears quite volcanic. Prof. Aughey, of Nebraska University, has lately examined the region and concludes that the phenomena are the results of local chemical action. The upper surface of the bluff is carbonate of lime; under this is a stratum of potter's clay which contains iron pyrites, together with carbonate of magnesia and alumina. The decomposition of the iron pyrites liberates sulphuric acid and the percolation of water brings it into contact with the carbonates, thus developing great amounts of heat, steam and carbonic acid.—*Fortsch. der Zeit.* C.

Modifications of Ampere's Laws.—Max Margules has communicated to the Vienna Academy the results of his researches upon "The Theory and Application of Electro-Magnetic Rotation," which he embodies in the two following laws: 1. If the pole of a magnet rotates in the neighborhood of an unclosed conductor, about an axis which is within the magnet, a current will be induced within the conductor; but if a rectilineal conductor is turned about its own axis, in the neighborhood of a magnetic pole, no current will be produced in it. 2. The rotation of a magnetic pole around a rectilineal conductor induces no current, but the rotation of the conductor about the pole produces an induced current. The first portion of the first law is a simple inversion of Ampere's statement of the law of electro-magnetic rotation; it has also been demonstrated by F. E. Naumann, and adopted as a fundamental law of the phenomena of uni-polar induction. But W. Weber, who first specially investigated the phenomena to which Faraday invited attention, disputes the sufficiency of Ampere's explanation of the rotation of a magnet on its own axis when it is traversed by a galvanic current.—*Ann. der Phys. und Chem.* C.

Fire-proof Paper for valuable documents may be made from one part vegetable fibre, two parts asbestos, $\frac{1}{10}$ of a part borax, $\frac{9}{10}$ of a part alum. A fire-proof ink for the same may be made from 850 grains graphite, 80 grains copal varnish, 75 grains copperas, 300 grains tincture of galls and indigo-carmine.—*Der Techniker.* C.

Franklin Institute.

HALL OF THE INSTITUTE, March 19th, 1879.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

The President announced the appointment of Dr. Isaac Norris to fulfill the duties of Secretary *pro tempore.*

There were present 172 members and 35 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 13 persons were elected members of the Institute, and the resolution of the Board that the Elliot Cresson Gold Medal is hereby awarded to Henry Bowers, of Philadelphia, in accordance with the recommendation of the Committee on Science and the Arts (reported to the Board of Managers Oct. 9th, 1878), for having introduced into the United States the manufacture of "Pure Inodorous Glycerine." He also reported from the same committee the following resolution, passed on the 5th instant:

Resolved, That the Elliot Cresson Gold Medal be awarded to Norbert de Landtsheer, of Paris, France, for his machine for treating flax, hemp, etc., and that the usual publication be made by the Actuary in the JOURNAL OF THE FRANKLIN INSTITUTE of the proposed award of said medal.

The Actuary also reported the following resolutions:

Resolved, That the Board of Managers have learned with deep regret of the death of Mr. J. B. Knight, late Secretary of the Franklin Institute; that we bear testimony to his zeal, faithfulness and ability, and will unite in paying our last tribute of respect by attending his funeral on the day appointed.

Resolved, That a committee of three be appointed, including the President of the Institute, who shall be chairman, to prepare a memorial of Mr. Knight, to be recorded on our minutes and to be presented to the Institute as an expression of the feelings of this Board.

To this service Mr. Coleman Sellers and Mr. Theodore D. Rand were appointed with the President.

The following memorial was then read by the Secretary *pro tem.*

JACOB BROWN KNIGHT, late Secretary of the Franklin Institute, was the son of George J. Knight and Abi Brown, his wife, and was born near Brownsville, Jefferson County, N. Y., upon the 2d of June, in the year 1833.

His ancestors, Giles and Mary Knight, were members of the Society of Friends, and came to America with William Penn, in the ship *Welcome*, in the year 1682. They settled in Byberry, Philadelphia County, Pa., where their descendants are numerous.

His grandfather, Israel Knight, in 1804, bought a tract of land at Black River, in the State of New York, and with seven of his neighbors visited the place, but concluded to let his children settle there, he himself returning to the old homestead.

Accordingly, his son George removed to Black River, with his family. The subject of this memoir was named after an uncle of his mother, Major-General Brown, a distinguished officer of the war of 1812.

He received his early education at the Watertown Institute, and in his youth exhibited a taste for mechanical pursuits. He afterwards received a practical training in the machine works of Hoard & Sons, Watertown, and in those of Merrick & Sons, in this city.

His health failing, in 1855 he went to the South and was engaged in the erection of sugar and cotton machinery, when the breaking out of the rebellion proved disastrous to his fortunes. He then became a consulting engineer in the city of New Orleans, and was an officer of a society of engineers established there, and was an occasional contributor to DeBow's Review.

Mr. Knight was elected a member of the Franklin Institute September 13, 1873, and evinced his interest in this body by occasional gratuitous services.

In April, 1874, as a member, he volunteered his assistance in the preparations for the Exhibition to take place in the ensuing fall. His offer was at once accepted, and all of his spare time was devoted to the work, without compensation. In this position his assiduity, good judgment, zeal, intelligence and good address, pointed him out as a suitable person for the position of General Superintendent, and to this position he was appointed by the Chairman of the Committee on Exhibitions, upon the 1st of July, 1874, after three months of observation and without any other influence urging the choice.

The event fully justified the appointment, and it would be a repetition of the same language to enumerate the qualities he exhibited in his new position. The exercise of these qualities contributed largely to the great success of the Exhibition.

Afterwards, he was appointed by the President, Secretary *pro tem.*

pore of the Institute, and was elected to that office at the annual election in January, 1875. He was continued in the office by successive re-elections, and exercised the functions until about ten days before his lamented death, which occurred upon the 10th of March, 1879.

Mr. Knight had not the advantage of early scientific training. He graduated at the vise-bench at a time when machine tools were far from perfect, and when nearly everything depended upon the skill and accuracy of the workman. He acquired most of his knowledge in the hard school of experience, but in this school he was always a student and learned fresh lessons at every turn of fortune. The knowledge he thus acquired was both various and extensive. It was firmly held and always available.

He had a just judgment of his own powers, which gave him courage to attempt and accomplish what seemed to be beyond them; but he had no false pretensions, and, if insufficiently acquainted with a subject, he was free to confess it and to ask for assistance, which the magnetism of his character and his continued zeal for the interests of the Institute disposed all around him to render.

It was thus as Secretary and as editor of the JOURNAL, he was able to avail himself of the ample resources in talents and special acquirements of the members of the Institute and to wield them for its benefit, and to accomplish more than any one, unaided, could have done.

One illustration of his methods may be recorded. It was at his suggestion that the Committee on Dynamo-electric Machines was raised last year. In personal composition the committee contained all the ability and science requisite for the work, which involved delicate measurements of power, light, heat and electricity in its several functions. The work was patiently pursued and successfully accomplished, but often, after the day's work of the committee had been finished, the Secretary would remain behind and repeat the experiments and observations for his own instruction.

At the time of his death, Mr. Knight was Secretary of the Franklin Institute, Editor of the JOURNAL of the Institute, Representative of the Institute in the Board of Trustees of the Pennsylvania Museum and School of Industrial Art, Vice-President of the Young Engineers' Club, and Member of the American Philosophical Society.

He was stricken down in the full career of public usefulness, and at a time when he had every prospect of future distinction.

The Board of Managers of the Franklin Institute, to testify their sorrow for the loss of an able and faithful officer, record upon their minutes this tribute to his memory.

Mr. William V. McKean moved that the paper just read be recorded upon the minutes of the Institute, which was adopted.

The following resolutions from the Executive Committee of the Pennsylvania Museum and School of Industrial Art were read:

Resolved by the Executive Committee of the Trustees of this School, That we learn with deep regret of the sudden death of Mr. J. B. Knight, late Representative of the Franklin Institute in this corporation. We have found him to be a faithful and active co-worker in this institution, and a fitting representative of the oldest Mechanic's Institute in America.

Resolved, That a copy of this resolution be sent to the President of the Franklin Institute, with a request that he have it presented at the next meeting of the Institute, as an evidence of our respect for their late Secretary.

Mr. John J. Weaver moved that the resolutions read from the Pennsylvania Museum and School of Industrial Art be entered on our minutes, which was adopted.

The Committee on Library reported the following donations:

Map of the United States and Territories.

Annual Reports of the Commissioner of the General Land Office for 1877 and 1878. From the Commissioner of General Lands.

Annual Report of the Supervising Architect to the Secretary of the Treasury for the year 1878. From the Supervising Architect.

Forty-sixth, Forty-eighth and Forty-ninth Annual Reports of the Board of Commissioners of Public Schools of Baltimore. 1874, 1876 and 1877. From the Board of Commissioners.

Reports of the Inspectors of Mines of the Anthracite Coal Regions of Pennsylvania for 1873—1877.
From the Inspector of Mines, Harrisburg.

Annual Report of the Commissioner of Agriculture for 1877 and 1878. Washington, 1878.
From the Commissioner of Agriculture.

Annual Reports of the Secretary of the Navy for the years 1872, 1873, 1875, 1876 and 1878. From the Secretary, Washington.

Catalogue of Brooklyn Library. Parts 1 and 2.
From the Library, Brooklyn, N. Y.

First to Third Annual Reports of the New Jersey State Board of Agriculture for 1873—1875. From the Board.

First to Eighth Annual Reports of the Department of Health of the City of Chicago. 1870—1877. From the Department.

Annual Reports of the Canal Commissioners of the State of New York for 1874 and 1877.
From the Department of Public Works, Albany, N. Y.

Eighth Report of the Board of Trustees of the Illinois Industrial University for 1876. From the University.

Annual Report of the Secretary of the Treasury on the State of the Finances for 1878. From the Secretary, Washington.

Monthly Reports of the Kansas State Board of Agriculture for February, March, November and December, 1877; and May—December, 1878.

Reports of the Kansas State Board of Agriculture to the Legislature for 1873, 1875 and 1876. From the Board.

Annual Report of the Commissary-General of Subsistence to the Secretary of War for 1877.

Official Army Register for January, 1878.
From the Secretary of War, Washington.

Report of Meteorological Council to the Royal Society for Ten Months ending 31st March, 1878.
From the Meteorological Committee of the Royal Society.

Peabody Institute of Baltimore. Eleventh Annual Report. 1878.
From the Institute.

Twenty-sixth Annual Report of Boston Public Library. 1878.
From the Library.

Annual Report of the Commissioners of Fairmount Park, Philadelphia, for 1878. From the Commissioners.

Annual Report of the Commissioner of Internal Revenue for the year 1878. From the Secretary of the Treasury, Washington.

Charter and By-Laws of the Maryland Institute for the Promotion of the Mechanic Arts, and Report of the Twenty-eighth Exhibition. 1878. From the Institute.

Twenty-third Annual Report of the Board of Education of the City of Chicago for 1877 From the Department of Public Instruction.

Legislative History of Subsistence Department of the United States Army for 1775—1876. By J. W. Barriger.
From Secretary of War, Washington.

Annual Report of the Secretary of Internal Affairs of Pennsylvania for 1878. 2 parts in 1 vol. From J. S. Africa, Harrisburg.

Annual Report of the Light-house Board to the Secretary of the Treasury for 1878. From the Board, Washington.

Digest of Opinions of the Judge-Advocate-General of the Army. Edited by Major W. Winthrop. 3d edition.
From the Secretary of War.

New and Original Theories of the Great Physical Forces. By Henry Raymond Rogers. Dunkirk, N. Y. 1878.
From the Author.

Ordnance Memoranda. No. 21. Ammunition, etc., etc. 1878.
From the Chief of Ordnance, Washington.

Classification of the Collection to illustrate the Animal Resources of the United States. By G. Brown Goode. 1876.

Bulletin of the United States National Museum. No. 3. By J. H. Kidder. 1876.

Report of United States Geological Survey of Territories. F. V. Hayden. Vol. 1, Fossil Vertebrates, and Vol. 5, Zoology.
From the Secretary of the Interior, through Hon. Charles O'Neil, House of Representatives, Washington.

Specifications and Drawings of Patents issued from the United States Patent Office for September, 1878.
From the Commissioner of Patents, Washington.

Smithsonian Miscellaneous Collections. Vols. 13—15.

Annual Reports of the Board of Regents of the Smithsonian Institution for 1877. From the Institution, Washington.

First to Eighth Reports of the Directors of City Trusts. 1870—1877. From the Directors, Philadelphia.

Second Geological Survey of Pennsylvania. Reports upon Lehigh district; Azoic rocks, part 1; Fossil ore, Juniata Valley; Bradford, Tioga and Indiana Counties; and Museum Catalogue (D, D; E; F; G; 4 H; O). 1878.
From the Board of Commissioners, Harrisburg.

Twenty-seventh, Twenty-ninth, Fifty-eighth, Sixtieth, Eighty-ninth—Ninety-first Annual Reports of the Regents of the University of New York. From the University, Albany.

Report of the Thirteenth Industrial Exhibition under the Auspices of the Mechanics' Institute of San Francisco, Cal.
From the Institute.

Report of the Thirteenth Exhibition of the Massachusetts Charitable Mechanic Association in Boston. 1878.
From the Association.

Chemical Examinations of Sewer Air. By Prof. Wm. Ripley Nichols. Boston, 1879. From the Author.

The Design generally of bridges of very large span for railroad traffic. A paper by T. C. Clarke, of Philadelphia, before the Institution of Civil Engineers, London. 1878. From the Author.

Moorehead Clay Works' Illustrated Catalogue of Terra Cotta Ware.
From the Works.

American Institute of Architects. Proceedings of Third, Fifth to Tenth Annual Conventions. From the Institute, New York.

Fire-proof Floors Compared. By G. B. Post.

Remarks on Fire-proof Construction. By C. B. Wright.
From American Institute of Architects, New York.

Report of the Council of Education upon the Condition of the Public Schools of New South Wales for 1877. Sydney, 1878.

Journal and Proceedings of the Royal Society of New South Wales. 1877. Vol. 11. Sydney, 1878.

Remarks on the Sedimentary Formations of New South Wales. By Rev. W. B. Clarke. 4th edition. Sydney, 1878.

Annual Report of the Department of Mines of New South Wales for 1877. Sydney, 1878.

Report upon the Construction and Working of Railways of New South Wales during 1876. By John Rae. Sydney, 1877.
From the Royal Society of New South Wales.

Catalogue of Motala Iron and Steel Works, Sweden. Philadelphia, 1876.

Historical Notice of the Dutch Society of Sciences at Harlem. 1876.

Construction and Ameublement de Batiments d'école. Royaume de Belgique. Huy, 1876.

Hawaiian Almanac and Annual for 1876. By Thomas G. Thrum. Honolulu.

Noticia, etc., da exposiçâo do Parana. 1875.

Elementary and Middle-Class Instruction in the Netherlands. Leyden, 1876.

Official Record; containing Introduction, Catalogues, etc., of the Colony of Victoria at the Philadelphia Exhibition, 1876. Melbourne, 1876.

Denmark at the Centennial, 1876.

Collection of Russian Domestic Manual Labour. St. Petersburg, 1876.

Catalogue of Collections from the India Museum exhibited in Indian Department of Philadelphia Centennial Exhibition, 1876.

Agricultural Instructions for Brazil.

Exposiçāo des trabalhos historicos geographicos, etc., etc., exhibida na exposiçāo nacional de 1875. Rio de Janeiro, 1876.

Estudos sobre a quarta exposição nacional de 1875. Por J. de Saldanha de Gama. 1876.

Artisans' School. Rotterdam, 1869.

Report regarding Swiss Unions of Young Merchants. 1876.

Siamese Exhibits to Centennial Exhibition of 1876.

Catalogue of the Statuary and Paintings sent by Milan's Exhibition of Fine Arts. 1876.

Catalogue of Forest Trees of the United States.

Index to and Catalogue of Ordnance Collection.

Catalogue of Charities conducted by Women. 1876.

Catalogo degli espositori Italiani. Firenze, 1876.

Argentine Republic. By R. Napp. 1876.

Sketch of Public Works in Netherland. By L. C. Van Kerkwyk. Harlem, 1876.

Subsidios para a organisaçaõ da Carta physica do Brazil.

Catalogue of Articles and Objects exhibited by the Navy Department in the United States Government Building, Fairmount Park. Philadelphia, 1876.

History of Mexican Railway. By Baz and Gallo. 1876.
From Edward Shippen, Philadelphia.

Reports of Secretary of War, 1866—1876.
From the Secretary, Washington.

Prof. George A. König, of the University of Pennsylvania, then made some very interesting remarks upon a new branch of science connected with Chemical Analysis, for which he has proposed the name of Chromometry. Dr. König prepares beads of borax of a known weight, into which are fused a certain amount of the substance to be examined, and, after a careful preparation of them, the intensity of color is measured by means of a prism having a color complimentary to the bead under examination. The instrument, called the Chromometer, is an ingenious device of Dr. König, and is skillfully and beautifully made by Mr. Zentmayer, of this city.

The Secretary's report embraced Mr. L. T. Young's Microphone, a very ingenious and novel arrangement of this instrument. The form is that of a small box, with the usual telephonic mouth-piece on the top. Attached to the under surface of the diaphragm is cemented a small piece of rubber holding a carbon cup. A similar cup is placed on the inside of the brass ring employed for holding the ferrotype-plate diaphragm in its place. Each of the cups are connected with binding screws at the side. The rod of carbon rests lightly on the cups, and is covered with rubber; a small watch-spring bearing upon it near the middle. The spring is adjustable by means of a screw. This arrangement, it is claimed, does away entirely with the grating sound usual in other forms of microphones. The instrument is arranged so as to be placed against a wall or other support, the carbon rod being then in a vertical position.

Mershon's Patent Grate consists of a series of rotary bars having studs projecting from the sides. The one in the centre being capable of being lowered by a chain. The arrangement is such that air can pass in freely to every part of the fire, and the necessary motion is given by a lever. In practical operation it is found very satisfactory, and considerable saving of labor is effected by their use.

Blodgett's Improved Thermostat is intended to give an alarm of fire upon the slightest increase of temperature, operating upon the well-known principle of the unequal expansion of metals, (brass and steel firmly riveted together being used), closing a circuit with a battery and electric bell. They can be used in place of the ordinary push button by having a cord attached to the instrument.

Fleischman's Battery for Medical Use is very compact, and allows of using from one to twenty cells by the movement of a pin to its proper socket. The lid of the box is employed for holding a supply of electrodes, etc., and an ingenious arrangement raises and lowers the cells.

The Secretary then read a few notes he had made on the trial of the Testing Machine at the Watertown Arsenal, a link of hard wrought-iron being broken at a strain of 722,800 pounds. Sir. Joseph Whitworth's new measuring instrument was commented on for its minute divisions and mechanical accuracy. The new Krupp gun, the largest of steel ever made, weighing 72 tons, and having a calibre of 15¾ inches and a length of 32 feet 7 inches, the bore being 28½ feet. The gun is composed of steel throughout, and loads from the breech. Owing to the great length of the tube, it was made in two portions, carefully secured, while jackets or cylinders further strengthen the gun. The closing of the cylinder is done by a sliding wedge, and it is impossible to fire it until it is effectually closed. The charge will be 385 pounds of prismatic powder, and the chilled-iron shell used is to weigh 1660 pounds. Some remarks were then made on the cost of the great East River bridge in its unfinished state, and it was shown that the amount expended of over ten millions of dollars was greater than that of the Britannia and Victoria bridges combined.

Rapid transit crossings were next taken up, and the system known as the "interlocking" one explained, where the signals and the switches are all moved by levers placed in a solid frame in a commanding position. Each lever is connected with its respective switch or signal by rods and cranks, and yet the levers are so connected with each other that the movement of any one locks every other in the series. At the Moorgate street station, London, where 768 trains pass daily, this is done every 45 seconds in the nineteen hours the tracks are used. It was stated that 15 of these interlocking machines are now in operation in this country, and no danger need be experienced at crossings, even of elevated railroads, with their use.

The Secretary closed his remarks with a few data regarding the limit of human endurance, and showed that, taking Professor Trowbridge's calculation as the correct one, that a man with an average step lifts his own weight a foot from the ground in every 23 feet, he would expend an amount of force equal to a foot-ton every 368 to 400 feet traveled. Knowing the weight, the length of his pace and the height, we can determine how many feet he would have to walk to perform a work equal to one foot-ton. This exertion Trowbridge estimates as equal to lifting from thirteen to fifteen tons one foot high. In walking 500 miles, therefore, at the lower estimate, it would amount to 6,500 tons, as was recently done in New York by an Englishman in six days time less 38¾ hours, when he was not walking.

Mr. Coleman Sellers moved that the Secretary *pro tempore* represent the Franklin Institute as its Trustee in the Pennsylvania Museum and School of Industrial Art for the time of his appointment, which was carried.

Mr. Coleman Sellers also announced that the collection belonging to the American Institute of Mining Engineers, now exhibited in Memorial Hall, will be formally transferred to the Pennsylvania Museum and School of Industrial Art on Wednesday next, March 26th. The value of this collection is very great, and, in all probability, it could not be duplicated for one hundred thousand dollars.

On motion, the meeting adjourned.

ISAAC NORRIS, M.D., *Secretary pro tem.*

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"CONCERNING $\frac{T_1 - T_0}{T_1}$; OR, THE LIMIT OF EFFICIENCY IN HEAT ENGINES."

By PROF. R. H. THURSTON.

Fully appreciating the mathematical skill, the familiarity with heat-dynamics, and all the courtesy illustrated in the paper published recently in the JOURNAL under the above title, in which the "thermodynamic heresy" detected by its author is so ably attacked, and admitting the conclusions therein reached, the writer would suggest that the truth may be best exhibited by quite a different method.* In fact, the main question calls for but very brief consideration and may be solved by very simple logical methods, based on well-proven and generally known facts which have been determined by scientific investigation and upon principles equally well-settled and generally understood.

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* In justice to its author, it should be stated that the paper containing this "heresy" was prepared while he was suffering from nervous exhaustion and prostration due to various physical causes and mental anxieties, the extent and the effects of which were not at the time either realized or suspected. A long period of depression terminating in serious illness extending over many months, from which illness recovery has only recently been apparently assured, will account both for the original error and for its tardy recognition.

The question primarily at issue in the case considered was whether the thermal changes of energy occurring in a fluid doing work and having work done upon it when its constitution is that of a perfect gas, were essentially different so far as they affect adjacent bodies, from those occurring when the working substance condenses during expansion against resistance, as does steam in the steam engine. This point settled, no further discussion is needed.

The question being, whether all working substances are, as transferrers of heat, equally efficient in heat engines, the case is covered by a well-known principle of mechanics:—In any mass or system of bodies, no interchanges of energy and no interaction of forces among those bodies can produce any change in the action of the mass upon bodies external to itself.

Now, as the characteristics which distinguish perfect gases from those which, like steam, condense while doing work upon external bodies, are due entirely to differences in interactions occurring among their molecules due to their own internal and inherent attractive (and possibly inherent repellant) molecular forces, it at once follows that, as receivers and transmitters of heat energy to external bodies, they will be alike and subject to the same laws. No interchange of energy externally, such as results in the closer approximation of the particles of one portion of a vapor, in consequence of its surrender of energy to other molecules, can affect the action of the mass, as a whole, upon bodies external to itself.

Another statement, equally simple, may serve:—A given quantity of heat entering an engine and doing work therein—whatever the amount and whatever the conditions—that quantity of heat energy has, initially, a measure Mh, in which M measures the quantity of matter, *i. e.*, the mass of the working substance, and h is the virtual head which, multiplied into M, gives a product equal to the total initial energy. All subsequent changes which attend the operation of the engine are due to variations in the value of h; since they are all due either to changes of molecular velocities with changing temperature or to changes of molecular distances due to modification of repellant forces and changes in the total quantity of heat present in the expanding or contracting mass.

Throughout every operation, the value of M remains constant and must so remain as long as the law of the persistence of matter continues. If then, the mass remains constant, it is a matter of indifference, so far as any thermodynamic action is concerned, what kind of matter has given the value M. This being the case, it is a matter of indifference, in any thermodynamic problem, what working substance is used or assumed; every principle applies equally well whether the heat engine be a perfect gas engine, or a steam, or other vapor engine.

Proposition A—"It is impossible for any heat engine to perform work by the expansion and contraction of the volume of its working substance without rejecting heat"—is correct under all attainable conditions, so far as is yet known, and every such engine must reject heat.

The proposition, although correct, when rendered properly specific as intended, is if unqualified, not only not proven by the reasoning adopted, but may be disproved by the same general method and using the same quantities.

Thus: let the engine R be driven backward by S, as suggested in the JOURNAL, p. 154, the latter, however, acting under those conditions which admittedly imply rejection of heat, we then have:

$$W_1 = J\,(Q_1 - Q_0) \text{ and } W^1{}_1 = J\,(Q^1{}_1 - Q^1{}_0);$$

then.

$$Q_1 - Q_0 = Q^1{}_1 - Q^1{}_0,$$

and if the two engines take in heat at the same temperature, it follows that the engine S, by exerting a certain quantity of energy between the initial temperature t and a lower temperature t_0, may convey an equivalent amount of heat from the grade t_1 to a higher temperature t_2. The point here overlooked is the fact that $Q_0 > Q^1{}_0$.

Now suppose that S works down to absolute zero, and thus avoid the rejection of heat, we have, as in the original:

$$J\,(Q_1 - Q_0) = J\,(Q_1{}^1 - Q_0{}^1) = J\,Q^1{}_1, \text{ and}$$
$$Q_1{}^1 = Q_1 - Q_0$$

and it follows—since S certainly does not now reject heat, for none is left to reject—that the second principle assumed is false, as well as that it is possible for a heat engine to perform work without rejecting heat. The true conclusion is obviously that *only under certain conditions, which we cannot now see any way of securing, can a heat engine do work without rejection of heat.*

Proposition A, to be correct, requires this limitation, and the second assumed principle is as evidently defective in not being sufficiently specific. This latter fact has been fully recognized by Maxwell, Tait and other writers. As put by Clausius, "heat cannot, of itself, pass from a colder to a warmer body," it is sufficiently and obviously right and is analagous to the statement, "Water cannot, unaided, flow upward."

Thompson's statement, "It is impossible, by means of inanimate material agency, to derive mechanical effect from any portion of matter by cooling it below the temperature of the coldest of the surrounding objects" is analagous logically, not physically, to the statement that "no machine can, of itself, cause water to flow upward." In either case, the desired effect can be actually produced only, so far as we now know, by the sacrifice of some part of an original stock of energy. Clerk-Maxwell, it is true, has suggested in his so-called "demon hypothesis," how it is at least conceivable that work might be done by cooling any mass of elastic gas or vapor below the temperature of surrounding bodies, and the writer has suggested a singular and equally conceivable "physical possibility" by which the same result is reached; but both are equally impracticable.

It is readily seen why it has been difficult to frame a correct enunciation of the principle. It is one of those facts which come of natural conditions which can be learned, and limitations detected, only by experiment, or by mathematical deduction from experimentally proven laws, based in turn on facts shown by experiment or by observation; it is not a general law in the same sense with the "first law" of thermodynamics. We can only assert that it is correct under all conditions which seem to us attainable, and that the results are then practically the same as if it were an absolute and mathematically accurate general principle.

It may be seen that the efficiency of an actual engine is dependent, not only upon the range of temperature adopted, but also upon the method of disposing of heat rejected. Our theory assumes the absolute impossibility of avoiding rejection of heat or of exchanging that of low for that of high grade, or for available natural energy of any other kind.

The whole matter is briefly and well summed up by Tait, who says:* "therefore, *so far as experiment goes, and practical application goes*" (the italics are introduced by the writer), "we may take this improved form of Carnot's demonstration as being absolutely decisive of the important result that no heat engine can be more perfect than a reversible one." We cannot say what experiment may reveal in the future, or what practical applications may follow. We can only assert that it, to-day, seems impossible to do work by the expenditure of heat energy without waste by rejection of energy from the system as a whole, and that it is not known to this day whether or not we must go on throughout the life of the race, or until all mankind is driven into the tropics by the exhaustion of our fuel supplies, wasting a large percentage of all the heat energy now treasured up in our coal fields.

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* "Recent Advances in Physical Science," by P. G. Tait, M. A., London, 1876.

The facts and premises and the logical argument which would best suit the majority of readers perhaps, reads thus :—

1. We know, at present, no other way of making heat energy available in engines than through changes in volume and density of masses pervaded by it.

2. We know, at present, no practicable way of discharging heat from the working substance of a heat engine except by presenting to it a mass at lower temperature.

3. We know, at present. no way of compressing a mass of matter containing heat—that heat not being removed from the mass—without the production of an additional amount of heat precisely equal to that which disappears in the opposite equal change of expansion.*

4. "Heat will not, of itself, pass from a colder to a warmer body."

5. No way is known, at present, of working an expanding body in any heat engine down to the absolute zero of temperature—and thus of depriving it of all heat energy—or of approximating to that state.

6. All heat engines are worked in the presence of and surrounded by matter having a temperature several hundred degrees above absolute zero, which thus presents to the working fluids of such engines a kind of "sea-level" of heat energy.

Now, in every such engine, the working substance having driven the piston to the end of its stroke and thus having attained to a maximum as to volume, and to a minimum as to contained heat energy, it must either be rejected from the cylinder or must be restored to its initial and minimum volume.

But, as just shown, the one operation compels its expulsion with all its heat contents, against the extraneous pressure due to the presence in the resisting fluid of heat energy at or above the "sea-level" of temperature, while the other action can only occur by compression, with abstraction by surrounding bodies of all heat due to such reduction of volume.

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* It is, however possible, as shown by Joule, for change of volume to occur without transfer of heat. Work must be done to cause change in total amount of heat energy.

Hence, in all heat engines, so far as we now know, there must be a rejection of unutilized energy from the working cylinder, the proportion of initial heat to that thus lost being determined by the working temperatures adopted, and the absolute amount of waste per pound of working substance being determined by its physical properties and the distance of the absolute zero below minimum working level of temperature.

TESTS OF A BALDWIN LOCOMOTIVE.

By John W. Hill, M. E.,
Member American Society of Civil Engineers.

(Continued from vol. lvii, page 272.)

In the following table the diagrams have been worked in pairs for each engine (right and left), and are given with the boiler pressure, revolutions, and the track, for each series of cards. The series are numbered from 1 to 40, Cincinnati to Hamilton; from 1 to 20, Hamilton to Twin Creek, and from 1 to 21, Twin Creek to Dayton.

In column 1 is given the order in which the diagrams were taken; column 2 gives the pressure in the boiler taken simultaneously with the diagrams; column 3 contains the revolutions corresponding with each series of diagrams. As already explained, the engine counter failed after running a short distance, and the revolutions are deduced from the observed time in running between fixed stations. This method, although not as desirable as an actual record of the revolutions by speed counter, was the only means by which the speed could be noted after the counter broke and cannot be in error sufficiently to affect the final results. The distances between stations (of which there were ninety-six in a run of fifty-nine miles) were carefully measured, after the tests, and the time in running from one station to the next was noted to seconds, and by the observer entered in his note book.

Columns 4 and 12 contain the initial pressures averaged for each pair of cards. This is the pressure at commencement of stroke and, as will be observed, is approximately the same for both engines during each of the three runs. Columns 5 and 13 contain the cut-offs in fractions of stroke measured on the cards. The entire valve motion is earliest for the right engine, although by the marks on the the guide bars, the valve motions were alike for both engines. Columns 6 and 14 contain the fractions of stroke to release. Columns 7 and 15 contain the terminal pressures, or pressures at time exhaust opens. (All pressures are measured from the atmosphere.) Columns 8 and 16 contain the counter pressures at mid-stroke. The effect of speed and terminal pressure on the back pressure will be apparent upon comparison of the values in these columns with the corresponding values in columns 3–7 and 15. Columns 9 and 17 contain the fractions of stroke, estimated from zero to exhaust closure. Columns 10 and 18 contain the mean effective pressure per square inch of piston during stroke (forward and back). Columns 11 and 29 contain the indicated horse-power for each pair of diagrams. The extreme variableness of the resistance under different conditions of speed and track are apparent from these values and the values in column 20 (where the aggregate indicated power is given). For diagrams 39, run from Cincinnati to Hamilton, the aggregate indicated resistance, including friction of the engine in all parts and extra friction due to load, was 30·641. At this time the engines were running "throttled" and "cut back" at less than seventy-nine revolutions per minute, whilst in diagrams 32, with an average cut-off ·58 of stroke and open throttle at 208·33 revolutions per minute, the engines were developing, in the aggregate, 726 horse-power, a mean of 363 horse-power per engine. In column 21 is given the conditions of the track, curve or tangent, grade up or down, deflection of curve, angle at centre and ratio of grade.

As suggested early in the review of the test, the engines were precisely alike, except the piston-rod of left engine was ·0625 in. in excess of standard diameter, otherwise the engines did not differ in measured dimensions; and without data to the contrary it would be reasonable to expect the engines to do equal amounts of work. A careful examination of the table of diagrams will show that, with a few exceptions, probably due to delay in taking the diagrams from opposite sides of the locomotive, the left engine was constantly carrying the heaviest load. In this engine the valve functions are all tardy as compared with the opposite side; but this alone is not sufficient to account for the discrepancy in the loads. According to the De Pambour law "the mean pressure on the piston is equivalent to the resistance" and any attempt to estimate the resistance from an indicator diagram assumes the correctness of this law. If the steam pipes branching to the cylinders were of unequal area in cross section, then the effect would be appreciated by a reduced initial pressure in the cylinder supplied by the least pipe, and this would appear to be the case in the run from Cincinnati to Hamilton, but in the runs from Hamilton to Twin Creek and from Twin Creek to Dayton the initial pressures differ very slightly.

With equal initial pressures and equal functions of valves, the mean diagrams should estimate alike, and in a coupled engine, when the load for a given interval of time is represented by a constant statical moment, each engine at two points in every revolution of the cranks must be capable of moving the load unaided by the opposite engine. Then by applying the De Pambour law to the problem, the mean pressure at the two points of crank should be equal for equal radii of cranks and opposite engines. If the pistons work on cranks at quarters, then the points at which one engine must be capable of moving the load at mean speed are 90° and 270° in the revolution of the respective cranks.

In a locomotive, when the axes of cylinders are in the same plane as the axis of drivers, then these points would represent a position of piston in excess of half stroke for the back motion, and less than half stroke for the forward motion, and the pressures at these two points referred to effective areas of piston should be alike.

Again, if the resistance to the motion of the engine be a constant quantity, then the mean effective pressure for total stroke into the mean crank arm (both cranks considered) should equal the pressure on the crank pin at 90° and 270° into the minimum crank arm.

The maximum crank for a pair of engines coupled at quarters would be 1·414, the actual radius of crank, and would exist when the cranks were respectively at angles of 45° and 235° from the centre line, and the minimum crank arm would exist when one pin was at 0° or 180° and the other at 90° or 270°, and the mean crank arm would be

$$\frac{1 \times 1{\cdot}414}{2} = 1{\cdot}207 \text{ times the actual radius of crank.}$$

In brief, the maximum crank arm for an engine working singly is the minimum crank arm for a pair of engines coupled at quarters, and as the force applied to the minimum crank arm must be capable of moving the load at mean speed, it follows that this force into the minimum crank arm should equal the mean pressure into the mean crank arm (for both engines).

It has been suggested that the force on the minimum crank arm into the length of the arm, may be more or less than the mean force for whole stroke into the mean crank arm, and that the momentum of the engine will be increased or diminished accordingly as the moment of the force into the minimum crank arm is greater or less than the moment of resistance.

An engine operating under the conditions first named, would move forward without acceleration or retardation of speed so long as the cut-off, boiler pressure, and resistance was uniform. Whilst under the second conditions, the engine would move forward by successive impulses, and the motion would be accelerated or retarded as the pressure into minimum crank arm was greater or less than the mean pressure into mean crank arm.

In the condensed tables of engine performance, the averages of the table of diagrams are given, together with the duration of run, miles run, miles per hour and distribution of the load.

The friction of engine in all its parts was determined upon the return from Dayton to Cincinnati; the car, containing the observers and invited guests, being detached and the engine running at average speed, while friction cards were taken, as rapidly as the indicators could be worked, from both ends of each cylinder.

The power absorbed by the engine in overcoming frictional resistance is based upon the average of mean effective pressures from the friction diagrams and the speed for each run.

The extra friction due to load has been estimated at *five* per cent. of gross load: the power expended in moving the train is the difference between the indicated horse-power and power absorbed by friction.

In determining the cost of the power, the engines were charged with the total water pumped into the boiler. Some exception may be taken to this method of estimating the economy of performance, but while, for purposes of investigation, it is proper to separate the performance of the boiler from that of the engine, in actual use the economy of the one is largely dependent upon the other. The economy of the boiler might be excellent, whilst the design of the engines was such as to obliterate the efficiency of boiler and render the efficiency of the whole mediocre or poor, and conversely, a good design of engine may be prejudiced by the inferior duty of the boiler. Of the total quantity of feed pumped into the boiler a portion went into the dry pipe as water entrained, a portion was lost by frequent blowing of the safety-valve, and still another portion was lost by the whistle. In addition to these losses, the drain-cocks of the cylinders were occasionally opened, and a small quantity of steam was wasted in the attempt to make calorimeter observations. Taking the difference between the water pumped into boiler and steam delivered to the engines at *seven* per cent. of the total quantity, then of this quantity but *ninety-three* per cent. was properly chargeable to the engine.

The per centage of steam accounted for by the indicator becomes

$$\frac{85·068}{·93} = 91·47$$

for the run from Cincinnati to Hamilton;

$$\frac{80·271}{·93} = 86·31$$

for the run from Hamilton to Twin Creek; and

$$\frac{83·191}{·93} = 89·45$$

for the run from Twin Creek to Dayton; and the actual steam per indicated horse-power per hour, became for the three independent runs 30·02 pounds, 31·05 pounds and 29.72 pounds, respectively.

A 16 in. non-condensing Harris-Corliss engine, working at 500′ piston speed, initial pressure of 100 pounds above atmosphere and cutting off at $\frac{2}{10}$ of stroke, would require about 21·5 pounds of water per indicated horse-power per hour.

It has been suggested by an eminent English engineer, that of the total power developed by a locomotive, 25 per cent. was absorbed by the engine itself in overcoming friction and working the pumps. The pumps were on during the run for friction diagrams, and the power expended in this direction is embraced in the second quantity under the distribution ot the load.

During the run from Cincinnati to Hamilton the mean indicated load on the locomotive was 291·958 horse-power, and the mean total friction load 33·384 + 12·929 = 46·313 horse-power, and the percentage of total power absorbed by the engine itself in overcoming all resistances becomes

$$\frac{46·313 \times 100}{291·958} = 15·86.$$

During the run from Hamilton to Twin Creek, the mean indicated load was 368·658 horse-power, and the total friction load was 57·632 horse-power, and percentage of total power absorbed by the engine in overcoming all resistances becomes

TOR DIAGRAMS.

HAMILTON.

FT ENGINE.

15	16	17	18	19	20	21	
Pressure.	Counter Pressure.	Exhaust Closure.	Mean Effective Pressure.	Indicated Horse-power.	Aggregate Indicated Horse-power.	TRACK.	
·468	0·250	·1078	60·442	70·453	139·521	Curve, 1° 00′ def.; cen. angle, 16° 24′.	Level.
·500	0·250	·1078	47·412	65·708	130·983	Tangent.	“
·125	0·500	·1078	41·981	75·057	152·220	Curve, 1° 30′ def.; cen. angle, 16° 21′.	“
·910	2·000	·2275	70·326	172·194	334·244	“ 1° 00′ “ “ 24° 36′.	“
·937	1·875	·2275	74·064	213·290	416·184	“ 1° 00′ “ “ 11° 30′.	“
·000	2·000	·3265	58·208	148·977	283·467	“ 1° 30′ “ “ 33° 02′.	“
·437	2·125	·3265	55·118	136·757	262·302	“ 1° 45′ “ “ 49° 09′.	“
·312	1·000	·3265	46·567	116·675	160·754	Tangent.	Up grade, 1·910.
·750	0·500	·3265	51·543	129·142	250·875	“	“ “
·312	2·875	·2275	62·389	156·318	307·653	“	“ “
·650	3·062	·2275	66·902	180·264	351·746	“	“ 1·651.
·968	2·750	·2275	61·146	140·828	276·925	Curve, 0° 30′ def.; cen. angle, 6° 00′.	Level.
·437	4·875	·1824	64·764	163·128	325·357	Tangent.	Up grade, 1·376.
·093	5·000	·1824	62·735	121·118	242·621	“	“ 1·300.
·437	2·000	·1824	75·133	125·227	247·435	“	“ “
·125	2·500	·1824	80·768	134·620	264·789	“	“ “
·625	2·250	·1824	87·822	146·378	288·745	Curve, 1° 00′ def.; cen. angle, 32° 11′.	Up grade, 1·250.
·187	2·312	·1824	91·415	150·415	297·338	“ “ “ “ “	“ “
·875	1·937	·1824	87·216	161·354	321·041	Tangent.	Up grade, 1·293.
·312	1·937	·1824	93·440	172·866	340·487	“	“ “
·125	2·250	·1824	87·692	142·606	281·004	“	“ 1·260.
·312	2·500	·1824	88·848	161·580	318·100	Curve, 0° 45′ def.; cen. angle, 21° 11′.	“ 1·256.
·468	2·750	·1824	87·433	153·364	305·076	“ “ “ “ “	“ “
·125	2·312	·1824	92·055	149·083	293·553	“ 1° 00′ “ “ 14° 30′.	“ 1·250.
[illegible]	2·250	·1824	[illegible]	[illegible]	[illegible]	Tangent.	[illegible]

FROM THE INDICATOR DIAGRAMS.

CINCINNATI TO HAMILTON.

			Right Engine.								Left Engine.										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Diagrams.	Boiler Pressure.	Revolutions.	Initial Pressure.	Cut-off.	Release.	Terminal Pressure.	Counter Pressure.	Exhaust Closure.	Mean Effective Pressure.	Indicated Horse-power.	Initial Pressure.	Cut-off.	Release.	Terminal Pressure.	Counter Pressure.	Exhaust Closure.	Mean Effective Pressure.	Indicated Horse-power.	Aggregate Indicated Horse-power.	TRACK.	
1	130	48·59	68·075	·7000	·9331	48·312	0·250	·1119	50·200	69·068	68·812	·7222	·9372	45·468	0·250	·1078	60·442	70·453	139·521	Curve, 1° 00′ def.; cen. angle, 10° 24′.	Level
2	131	57·76	55·187	·7000	·9331	43·087	0·500	·1119	47·055	65·275	55·750	·7222	·9372	34·500	0·250	·1078	47·412	65·708	130·983	Tangent.	"
3	125	74·53	52·000	·7000	·9331	31·812	0·500	·1119	43·119	77·163	51·093	·7222	·9372	30·125	0·500	·1078	41·981	75·057	152·220	Curve, 1° 30′ def.; cen. angle, 10° 21′.	"
4	135	102·07	112·125	·4740	·8362	40·937	1·250	·3304	60·122	162·050	108·750	·5000	·8770	41·910	2·000	·2275	70·326	172·191	334·241	" 1° 00′ " " 24° 36′.	"
5	132	120·02	114·375	·4740	·8362	44·375	1·875	·3304	70·107	202·804	115·625	·5000	·8770	47·937	1·875	·2275	74·064	213·290	416·184	" 1° 00′ " " 11° 30′.	"
6	129	106·69	112·375	·3300	·8192	32·000	2·062	·3761	52·500	134·490	112·625	·3880	·8448	37·000	2·000	·3265	58·208	148·977	283·467	" 1° 30′ " " 33° 02′.	"
7	132	103·43	109·812	·3300	·8192	28·062	2·125	·3761	50·563	125·545	110·437	·3880	·8448	31·437	2·125	·3265	55·118	136·757	262·302	" 1° 15′ " " 40° 00′.	
8	120	104·45	46·375	·3300	·8192	10·031	0·875	·3761	17·577	44·079	95·437	·3880	·8448	27·312	1·000	·3265	46·567	116·675	160·754	Tangent.	Up grade, 1·910
9	119	104·45	104·000	·3300	·8192	28·750	2·375	·3761	48·542	124·733	101·000	·3880	·8448	29·750	0·500	·3265	51·543	129·142	250·875	"	" "
10	122	104·45	104·187	·4740	·8362	37·687	2·125	·3304	60·346	151·365	104·187	·5000	·8770	39·312	2·875	·2275	62·389	156·318	307·653	"	" "
11	117	112·32	107·625	·4740	·8362	40·000	2·375	·3304	63·585	171·182	108·750	·5000	·8770	42·850	3·062	·2275	66·902	180·264	351·716	"	" 1·651
12	112	96·01	102·475	·4740	·8362	37·500	2·000	·3304	50·037	136·007	103·875	·5000	·8770	37·968	2·750	·2275	61·116	140·828	276·925	Curve, 0° 30′ def.; cen. angle, 6° 00′	Level
13	109	105·00	95·562	·5580	·8001	43·000	2·500	·2450	64·317	162·229	95·562	·6000	·9022	44·437	4·875	·1824	64·764	163·128	325·357	Tangent.	Up grade, 1·370
14	115	80·48	92·088	·5580	·8001	42·312	2·875	·2450	62·878	121·503	93·375	·6000	·9022	43·093	5·000	·1824	62·745	121·118	242·621	"	" 1·300
15	120	69·48	103·750	·5580	·8001	48·750	1·750	·2450	73·255	122·208	103·750	·6000	·9022	49·437	2·000	·1824	75·133	125·227	247·435	"	" "
16	125	69·48	100·000	·5580	·8001	51·937	1·750	·2450	78·028	130·169	110·625	·6000	·9022	54·125	2·500	·1824	80·768	134·620	264·789	"	" "
17	134	69·48	117·750	·5580	·8001	58·687	1·875	·2450	85·339	142·367	118·406	·6000	·9022	59·625	2·250	·1824	87·822	146·378	288·745	Curve, 1° 00′ def.; cen. angle, 42° 11′	Up grade, 1·250
18	130	68·59	122·937	·5580	·8001	68·500	1·500	·2450	89·211	146·924	123·843	·6000	·9022	62·187	2·312	·1821	91·415	150·415	297·339	" " " " "	" "
19	135	77·12	116·688	·5580	·8001	57·500	1·375	·2450	86·238	159·687	118·093	·6000	·9022	57·875	1·937	·1824	87·216	161·354	321·041	Tangent.	Up grade, 1·250
20	129	77·12	121·437	·5580	·8001	62·562	1·750	·2450	90·523	167·621	125·125	·6000	·9022	63·312	1·917	·1824	93·440	172·866	340·487	"	" "
21	132	67·79	115·937	·5580	·8001	57·500	1·750	·2450	85·027	138·308	118·500	·6000	·9022	59·125	2·250	·1824	87·092	142·606	281·004	"	" 1·260.
22	129	75·81	118·937	·5580	·8001	58·625	1·750	·2450	85·988	156·520	120·437	·6000	·9022	59·312	2·500	·1824	88·848	161·580	318·100	Curve, 0° 45′ def.; cen. angle, 41° 11′.	" 1·256.
23	134	73·12	118·000	·5580	·8001	58·625	1·500	·2450	86·413	151·712	118·468	·6000	·9022	58·168	2·750	·1821	87·133	153·364	305·076	" " " " "	" "
24	130	67·51	121·375	·5580	·8001	59·625	1·750	·2450	89·127	144·470	121·125	·6000	·9022	62·125	2·312	·1824	92·955	149·083	293·553	" 1° 00′ " " 14° 30′.	" 1·250.
25	135	67·51	117·500	·5580	·8001	57·031	2·000	·2450	86·413	140·071	118·500	·6000	·9022	60·000	2·250	·1824	87·965	142·459	282·530	Tangent.	" 1·278
26	130	67·51	124·187	·5580	·8001	64·187	1·500	·2450	91·024	149·004	125·625	·6000	·9022	64·437	2·062	·1824	93·274	151·056	300·060	"	" "
27	135	71·05	117·187	·5580	·8001	57·500	1·875	·2450	84·576	144·284	118·125	·6000	·9022	58·750	2·375	·1824	85·664	146·006	290·290	Curve, 0° 45′ def.; cen. angle, 39° 00′	" 1·248
28	131	71·05	124·375	·5580	·8001	61·500	2·000	·2450	91·024	156·819	125·687	·6000	·9022	62·500	2·250	·1824	93·460	159·257	316·076	" " " " "	" "
29	131	81·77	118·651	·6618	·9075	67·250	2·062	·1982	94·635	185·801	120·437	·7000	·9140	64·875	2·937	·1331	95·235	186·807	372·608	" " " " "	" "
30	130	81·77	120·125	·6618	·9075	70·312	1·625	·1982	97·084	190·611	120·468	·7000	·9140	69·000	2·375	·1331	97·433	191·121	381·732	Tangent.	Level.
31	127	113·85	117·437	·5580	·8001	58·375	2·062	·2450	84·716	231·584	118·812	·6000	·9022	59·062	3·125	·1824	86·105	235·163	466·747	Curve, 1° 00′ def.; cen. angle, 24° 20′	Up grade, 1·209
32	120	208·33	108·875	·5580	·8001	51·875	6·687	·2450	72·348	361·892	108·812	·6000	·9022	53·187	8·687	·1824	72·845	364·049	725·941	Tangent.	Down grade, 1·5227
33	112	208·33	101·500	·5580	·8001	47·562	4·250	·2450	69·767	338·984	103·187	·6000	·9022	49·875	4·750	·1824	72·458	362·117	701·101	"	" 1·270
34	97	208·33	89·567	·3300	·8192	21·500	2·500	·3761	36·830	184·231	88·125	·3880	·8448	25·375	3·125	·3265	40·326	201·534	385·765	"	" 1·345
35	98	208·33	79·312	·3300	·8192	20·312	2·875	·3761	32·420	162·170	76·938	·3880	·8448	21·375	2·750	·3265	33·936	169·597	331·767	"	" "
36	97	170·84	76·125	·3300	·8192	17·500	3·000	·3761	27·665	113·548	78·500	·3880	·8448	21·375	4·500	·3265	31·842	130·575	244·123	Curve, 1° 00′ def.; cen. angle, 27° 18′.	" 1·455
37	99	155·00	54·875	·3300	·8192	6·375	1·375	·3761	6·705	24·968	64·000	·3880	·8448	16·250	4·250	·3265	23·265	86·556	111·524	Tangent.	" 1·625
38	112	139·25	43·750	·3300	·8192	6·093	2·937	·3761	5·759	19·252	35·250	·3880	·8448	6·250	2·875	·3265	8·596	28·710	47·962	"	" 1·2694
39	92	78·80	33·000	·3300	·8192	4·875	2·000	·3761	7·586	14·371	34·125	·3880	·8448	7·000	3·500	·3265	8·596	16·270	30·641	"	" "
40	115	61·19	40·750	·5580	·8001	20·875	1·062	·2450	33·139	48·089	49·250	·6000	·9022	20·625	2·500	·1824	32·937	48·348	96·437	"	Level.
	122	100·475	97·272	·5066	·8095	42·547	2·166	·2736	63·447	141·782	99·812	·5486	·8879	44·640	2·653	·2160	66·484	150·175	291, 958		

HAMILTON TO TWIN CREEK.

1	125	42·02	114·125	·5580	·8001	55·531	1·000	·2450	83·477	84·222	107·437	·6000	·9022	63·187	4·000	·1824	87·514	88·214	172·436	Tangent.	Level.
2	120	95·23	110·843	·5580	·8001	50·000	2·250	·2450	73·731	168·580	108·031	·6000	·9022	56·087	3·000	·1824	76·952	175·565	344·154	Curve, 1° 00′ def.; cen. angle, 18° 15′.	"
3	123	107·89	108·818	·5580	·8001	50·250	4·625	·2450	72·937	188·947	109·062	·6000	·9022	56·125	5·000	·1824	76·801	199·264	388·211	Tangent.	Up grade, 1·644.
4	130	113·46	114·937	·5580	·8001	54·312	6·062	·2450	77·216	210·358	112·937	·6000	·9022	58·062	7·000	·1824	79·597	216·645	427·003	"	" 1·467
5	125	113·46	105·000	·5580	·8001	48·250	4·562	·2450	69·913	190·462	101·000	·6000	·9022	52·125	7·375	·1824	72·705	197·888	388·350	"	" "
6	120	113·46	103·500	·5580	·8001	49·625	3·656	·2450	71·942	195·988	114·562	·6000	·9022	52·062	4·531	·1824	73·233	199·324	395·312	"	" "
7	118	106·14	104·250	·5580	·8001	50·562	2·500	·2450	72·138	183·844	104·750	·6000	·9022	51·125	3·500	·1824	74·466	189·605	373·449	"	" 1·339.
8	128	114·19	114·187	·5580	·8001	55·218	4·187	·2450	79·186	217·110	114·781	·6000	·9022	57·187	5·687	·1824	80·443	220·358	437·468	Curve, 1° 00′ def.; cen. angle, 22° 30′	" 1·11023
9	130	114·19	109·437	·5580	·8001	57·000	8·375	·2450	72·207	198·225	108·125	·6000	·9022	51·375	6·750	·1824	73·274	200·719	398·944	Tangent.	" 1·941.
10	122	134·29	105·500	·4740	·8362	37·437	5·000	·3304	57·308	184·786	107·437	·5000	·8770	41·000	6·375	·2275	60·088	193·572	378·358	"	" 1·1124
11	116	114·86	99·687	·4740	·8362	34·375	4·687	·3304	54·051	149·060	101·437	·5000	·8770	37·875	6·250	·2275	55·944	154·138	303·204	"	" "
12	128	142·23	110·375	·3300	·8192	28·875	4·000	·3761	48·554	165·813	111·500	·3880	·8448	34·625	4·500	·3265	52·058	177·619	343·432	"	Down grade, 1·384.
13	130	135·67	107·087	·3300	·8192	30·525	7·750	·3761	44·864	140·136	114·937	·3880	·8448	34·250	7·875	·3265	48·705	158·574	298·710	"	" 1·789.
14	135	170·21	122·344	·3300	·8192	33·062	10·875	·3761	45·927	187·698	121·750	·3880	·8448	37·250	8·437	·3265	51·781	211·485	399·183	"	Up grade, 1·1625
15	132	146·70	107·937	·3300	·8192	28·187	5·625	·3761	44·899	153·925	108·687	·3880	·8448	33·750	5·937	·3265	49·661	174·767	328·692	Curve, 1° 00′ def.; cen. angle, 24° 30′	" 1·1750.
16	130	205·56	111·281	·3300	·8192	29·750	5·812	·3761	45·519	224·667	113·125	·3880	·8448	33·875	6·250	·3265	51·088	251·924	476·591	Tangent.	Level.
17	120	120·23	98·375	·5580	·8001	34·562	7·003	·2450	61·749	178·258	99·000	·6000	·9022	48·312	8·062	·1824	65·478	188·857	367·115	Curve, 0° 50′ def.; cen. angle, 40° 00′.	Up grade, 1·495
18	115	107·00	97·062	·5580	·8001	43·937	6·500	·2450	61·662	171·265	97·812	·6000	·9022	46·500	7·937	·1824	64·853	166·465	337·730	Tangent.	" 1·534
19	114	177·02	92·087	·5580	·8001	41·250	8·437	·2450	55·267	238·005	94·687	·6000	·9022	44·437	9·500	·1824	59·047	254·149	492·754	"	Down grade, 1·2250.
20	115	109·17	94·750	·5580	·8001	41·375	8·125	·2450	58·780	154·102	96·937	·6000	·9022	46·250	9·000	·1824	61·852	161·983	316·085	"	Up grade, 1·584
	124	124·179	106·054	·4928	·8069	43·204	5·405	·2863	62·515	170·083	107·538	·5370	·8850	46·774	6·353	·2220	65·812	180·055	368·659		

TWIN CREEK TO DAYTON.

1	140	51·00	135·000	·6618	·9075	79·500	1·125	·1982	111·190	136·157	136·750	·7000	·9140	84·687	0·875	·1331	112·320	137·391	273·548	Tangent.	Up grade, 1·976.
2	140	86·46	128·906	·5580	·8001	66·500	2·750	·2450	93·082	193·242	130·000	·6000	·9022	68·875	2·750	·1824	96·171	199·171	392·413	"	" "
3	133	121·84	111·406	·5580	·8001	51·750	6·625	·2450	72·870	213·102	111·687	·6000	·9022	56·218	6·500	·1824	76·588	223·836	436·938	"	" "
4	125	121·84	108·187	·5580	·8001	50·343	6·500	·2450	71·129	208·070	107·750	·6000	·9022	54·062	6·931	·1824	74·117	216·610	424·680	"	" "
5	130	127·47	112·912	·4740	·8362	41·687	4·250	·3304	63·265	193·722	111·875	·5000	·8770	45·375	5·500	·2275	65·985	201·465	395·187	"	" 1·540.
6	125	140·89	108·281	·4740	·8362	38·685	5·500	·3304	58·616	198·289	110·468	·5000	·8770	41·937	7·250	·2275	61·574	208·108	406·397	Curve, 1° 00′ def.; cen. angle, 38° 00′.	Level.
7	120	140·89	102·250	·4740	·8362	35·000	6·000	·3304	52·069	176·145	103·125	·5000	·8770	37·937	7·375	·2275	54·809	185·344	361·489	Tangent.	Up grade, 1·2761
8	119	145·32	100·187	·4740	·8362	34·427	6·000	·3304	53·103	185·289	102·812	·5000	·8770	38·593	7·937	·2275	54·816	191·092	376·381	Curve, 1° 00′ def.; cen. angle, 41° 00′.	Level.
9	118	149·38	100·562	·4740	·8362	34·250	6·500	·3304	53·148	191·707	100·250	·5000	·8770	40·062	8·437	·2275	55·478	198·806	390·513	" 1° 02′ " " 41° 08′.	
10	116	161·55	98·062	·4740	·8362	33·000	6·000	·3304	52·758	204·044	101·187	·5000	·8770	47·937	7·718	·2275	53·745	208·242	412·886	Tangent	Up grade, 1·3491.
11	120	145·50	110·625	·4740	·8362	38·625	7·250	·3304	59·820	208·987	108·250	·5000	·8770	40·312	7·625	·2275	57·631	201·454	410·441	"	" 1·978.
12	126	141·05	111·000	·4740	·8362	39·000	7·375	·3304	61·642	209·652	113·188	·5000	·8770	42·375	7·125	·2275	62·991	214·047	423·699	"	" "
13	130	144·53	111·250	·4740	·8362	38·937	7·000	·3304	60·601	210·300	113·593	·5000	·8770	43·500	7·875	·2275	63·167	219·008	429·308	"	" 1·1606.
14	128	157·30	107·500	·4740	·8362	37·937	8·187	·3304	57·421	216·875	110·906	·5000	·8770	42·812	8·156	·2275	59·564	224·745	441·620	"	Level.
15	122	151·90	101·937	·4740	·8362	35·250	8·125	·3304	51·883	189·230	104·843	·5000	·8770	38·031	8·812	·2275	54·237	197·598	386·828	Curve, 1° 30′ def.; cen. angle, 91° 52′	Up grade, 1·594
16	124	146·58	104·625	·4740	·8362	37·012	7·625	·3304	54·655	192·357	109·687	·5000	·8770	41·250	7·437	·2275	60·088	211·285	403·642	" 1° 00′ " " 28° 30′	" 1·2850
17	123	152·97	102·843	·4740	·8362	36·000	7·812	·3304	52·022	191·073	106·656	·5000	·8770	39·250	8·437	·2275	57·368	210·518	401·591	Tangent.	" 1·842
18	120	141·86	101·812	·4740	·8362	35·000	6·937	·3304	51·919	176·843	104·375	·5000	·8770	38·750	7·812	·2275	56·842	193·437	370·280	Curve, 1° 00′ def.; cen. angle, 11° 24′.	" 1·900
19	115	123·10	97·593	·4740	·8362	33·625	7·125	·3304	50·517	149·313	99·875	·5000	·8770	36·087	8·937	·2275	54·882	162·069	311·382	Tangent.	" 1·1057.
20	100	123·10	91·437	·6530	·9187	49·656	1·062	·1033	73·149	216·122	92·750	·6950	·9228	55·500	1·750	·1404	76·411	225·647	441·769	"	" "
21	100	123·10	64·687	·7000	·9331	40·000	0·500	·1119	55·122	162·925	42·875	·7222	·9372	25·625	1·250	·1078	35·414	104·577	267·502		
	123	133·25	105·280	·5142	·8558	42·199	5·726	·2935	62·394	191·623	105·743	·5437	·8871	45·180	6·646	·2067	64·005	196·876	388·502		

$$\frac{57{\cdot}632 \times 100}{368{\cdot}658} = 15{\cdot}63$$

During the run from Twin Creek to Dayton, the mean indicated load was 388·502 horse-power, and the total friction load was 61·487 horse-power, and the percentage of total power absorbed by frictional and pump resistances becomes

$$\frac{61{\cdot}487 \times 100}{388{\cdot}502} = 15{\cdot}82$$

or an average of 15·77 per cent. of the total indicated power was expended in overcoming the friction of the engine in all its parts, extra friction due to load and in working the pumps.

In presenting the cost of the power in coal, it is proper to remark that the coal burned during this trial was Pittsburgh No. 2, screened and picked, and is supposed to represent the best bituminous coal available in this part of the country (Cincinnati). Estimating the cost upon the basis of the actual coal burned, is prejudicial to the engines to the extent of unconsumed coal blown out of the stack, and of failure in the boiler to furnish a standard evaporation.

Taking the economy of engines as represented by 30·02, 31·05 and 29·72 pounds of steam per indicated horse-power per hour, or an average of 30·26 pounds for whole trial, and the evaporation per pound of coal (Pittsburgh) as 9 pounds, then the cost of the power becomes

$$\frac{30{\cdot}26}{7} = 3{\cdot}36 \text{ pounds.}$$

It will be remarked, upon examination of the condensed tables of performance of the engines, that whilst the cost of the power upon an evaporation of nine pounds of water per pound of coal is approximately the same for all the runs, the actual cost of the power is respectively 4·238, 7·033 and 5·359 pounds of coal per indicated horse-power per hour. The manifest unfairness of estimating the economy of the engines upon the coal actually burned, could not be better shown, for whilst the expense of steam per hour per horse-power is nearly the same for all runs, the actual coal burned varies from 27 per cent. excess during the third run to nearly 66 per cent. excess during second run, as compared with the coal burned per horse-power per hour during first run.

Assuming the Baldwin Locomotive as representing the best American practice, then two serious defects are apparent from these trials:

First. The economy of boiler should be improved until an average evaporation is had, of nine pounds of steam from temperature of feed per pound of coal. This evaporation is attainable without impairing the steaming qualities of the boiler.

Second. The valve gear should be so devised as to produce full port-opening for all cut-offs, and the area of port-opening should be calculated for maximum piston speed. It is just as desirable that the initial pressure in the cylinders of a locomotive shall approximate boiler pressure as in the automatic cut-off engine, and this result also is attainable without complicating the valve gear or diminishing the pronounced efficiency of the engine.

SUMMARY OF ENGINE PERFORMANCE.

Cincinnati to Hamilton.

July 28th, 1878.

Duration of run,	1 hour 26 minutes.
Miles run,	24·6950
“ run per hour,	17·2290
Mean revolutions per minute,	100·4730
“ piston speed each engine,	401·8920
“ boiler pressure,	pds. 122·0000

	Right Engine.	Left Engine.
“ initial pressure,	pds. 97·272	99·812
“ cut-off in parts of stroke,	·5066	·5486
“ terminal pressure,	“ 42·547	44·610
“ release in parts of stroke,	·8695	·8879
“ counter pressure at mid stroke,	“ 2·106	2·653
“ exhaust closure in parts of stroke	·2736	·2160
“ effective pressure,	“ 63·447	66·484
Grade of expansion including clearance,	2·124	1·961

DISTRIBUTION OF THE LOAD.

Indicated horse-power,	141·782	150·175
	291·958	
Power absorbed by engine above all resistances,	33·384	
Gross load,	258·574	
Extra friction due to load (·05 of gross load),	12·929	
Power expended in moving the train,	245·645	

COST OF THE POWER.

Steam per hour to the engines,	9424·60	
Piston displacement per hour to release	28842·31	29425·92

Piston displacement per hour to exhaust closure,	9075·49	7158·46
Volume of clearance per hour, . .	2520·98	2518·72
Weight of steam accounted for to release per hour,	4353·214	4588·809
" " " retained by cushion per hour .	497·909	426·874
" " " by diagrams (total), .	3855·305	4161·935
	8017·24	
Percentage of steam accounted for, . .	85·068	
Steam per indicated horse-power per hour by boiler, ...	32·28	
Steam per indicated horse-power per hour by diagrams, ...	27·46	
Coal per indicated horse-power per hour actual evaporation, . . .	4·238	
Coal per indicated horse-power per hour 9 to 1,	3·586	
Relative capacity of engines, . .	·9441	1·0000
" economy of engines, . .	1·0000	·9812

SUMMARY OF ENGINE PERFORMANCE.

Hamilton to Twin Creek.

July 28th, 1878.

	Right Engine.	Left Engine.
Duration of run, . . .	42 minutes.	
Miles run, ...	15·869	
Miles per hour, . . .	22·670	
Mean revolutions per minute, . .	124·1790	
" piston speed each engine, . .	496·7160	
" boiler pressure, . . .	124·0000	
" initial " . . .	106·654	107·538
" cut-off in parts of stroke, . .	·4928	·5370
" terminal pressure, . .	43·204	46·773
" release in parts of stroke,, . .	·8669	·8853
" counter pressure at mid stroke, .	5·495	6·353
" exhaust closure in parts of stroke, .	·2863	·2229
" effective pressure, . .	62·545	65·812
Grade of expansion, including clearance, .	2·183	2·004

DISTRIBUTION OF THE LOAD.

Indicated horse-power, . .	179·603	189·055
	368·658	
Power absorbed by engine above all resistances,	41·262	

Gross load, ...	327·396
Extra friction due to load (·05 of gross load).	16·370
Power expended in moving the train, .	311·026

COST OF THE POWER.

Steam per hour to the engines, . .	12311·94	
Piston displacement per hour to release,	35541·03	36261·85
" " " exhaust closure,	11737·62	9129·98
Volume of clearance per hour, . .	3115·80	3113·00
Weight of steam accounted for to release per hour,	5427·37	5849·11
" " retained by cushion " "	758·99	634·33
" " by diagrams, .	4668·38	5214·78
	9883·16	
Percentage of steam accounted for, .	80·271	
Steam per indicated horse-power per hour by boiler.	33·396	
	26·172	27·582
Steam per indicated horse-power per hour by diagrams, . . .	26·877	
Coal per indicated horse-power per hour by actual evaporation, . . .	7·033	
Coal per indicated horse-power per hour 9 to 1,	3·711	
Relative capacity of engines, . .	·9434	1·0000
" economy " " . .	1·0000	·9489

SUMMARY OF ENGINE PERFORMANCE.

Twin Creek to Dayton.

July 28th, 1878.

Duration of run. . . .	42·5 minutes.	
Miles run, ...	16·267	
Miles per hour, . . .	22.965	
Mean revolutions per minute, . .	133·25	
" piston speed each engine. . .	533·00	
" boiler pressure, . .	123·00	
	Right Engine.	Left Engine
" initial " . . .	105.209	105·743
" cut-off in parts of stroke, . .	·5142	·5437
" terminal pressure, . . .	42·199	45·180
" release in parts of stroke, .	·8558	·8874
" counter pressure at mid stroke. .	5·726	6·646

Mean exhaust closure in parts of stroke,	·2935	·2067
“ effective pressure,	62.394	64·005
Grade of expansion including clearance,	2·092	1·979

DISTRIBUTION OF THE LOAD.

Indicated horse-power,	191·623	196·876
	388·502	
Power absorbed by engine above all resistances,	44·276	
Gross load,	344·226	
Extra friction due to load,	17·211	
Power expended in moving the train,	327·015	

COST OF THE POWER.

Steam per hour to the engines,	12415·09	
Piston displacement per hour to release,	37648·70	39003.18
“ “ “ “ exhaust closure,	12911·60	9084·89
Volume of clearance per hour,	3343·41	3340·33
Weight of steam accounted for to release per hour,	5660·96	6138·47
“ “ “ retained by cushion per hour,	800·55	670·45
“ “ “ by diagrams,	4860·41	5468·02
	10324·43	
Percentage of steam accounted for,	83·191	
Steam per indicated horse-power per hour by boiler,	31·956	
Steam per indicated horse-power per hour by diagrams,	25·364	27·774
	26·569	
Coal per indicated horse-power per hour by actual evaporation,	5·359	
Coal per indicated horse-power per hour 9 to 1,	3·551	
Relative capacity of engines,	·9733	1·0000
“ economy “ “	1·0000	·9132

In the engraved diagrams, which by the liberality of the Baldwin Locomotive Works are made a part of this paper, all the original lines have been faithfully copied by Mr. J. Snowden Bell, who reproduced the cards for the engraver: and have been selected with a view to exhibiting graphically the action of the engines under test-trial. The diagrams have been worked together, and are cards of the same series from both engines.

The diagrams are produced in the following order:

TWIN CREEK, No. 1.

Right.

Boiler pressure,	140·
Initial "	135·
Cut-off in fraction of stroke,	·6618
Release " "	·9075
Terminal pressure,	79·50
Counter "	1·125
Exhaust closure,	·1982
Mean effective pressure,	111·190
Revolutions,	51.
Indicated horse-power,	136·157

Left.

Boiler pressure,	140·
Initial "	136·75
Cut-off,	·7000
Release,	·9140
Terminal pressure,	84·687
Counter "	·875
Exhaust closure,	·1331
Mean effective pressure,	112·320
Revolutions,	51.
Indicated horse-power,	137·391

CINCINNATI, No. 24.

Right.

Boiler pressure,	130·
Initial "	123·375
Cut-off in fraction of stroke,	·5580
Release. " "	·8901
Terminal pressure,	59·625
Counter "	1·75
Exhaust closure,	·2450
Mean effective pressure,	89·127
Revolutions,	67·51
Indicated horse-power,	144·470

Left.

Boiler pressure,	130·
Initial "	124·125

Cut-off in fraction of stroke,	·6000
Release “ “	·9022
Terminal pressure,	62·125
Counter “	2·312
Exhaust closure,	·1824
Mean effective pressure,	92·055
Revolutions,	67·51
Indicated horse-power,	149·083

CINCINNATI, No. 5.

Right.

Boiler pressure,	132·
Initial “	114·375
Cut-off in fraction of stroke,	·4740
Release “ “	·8362
Terminal pressure,	43·375
Counter “	1·875
Exhaust closure,	·3304
Mean effective pressure,	70·407
Revolutions,	120·02
Indicated horse-power,	202·894

Left.

Boiler pressure,	132·
Initial “	115·625
Cut-off in fraction of stroke,	·5000
Release “ “	·8770
Terminal pressure,	47·937
Counter “	1·875
Exhaust closure,	·2275
Mean effective pressure,	74·064
Revolutions,	120·02
Indicated horse-power,	213·290

CINCINNATI, No. 6.

Right.

Boiler pressure,	129
Initial “	112·375
Cut-off in fraction of stroke,	·3309
Release “ “	·8192
Terminal pressure,	32·000

Counter pressure,	2·062
Exhaust closure,	·3761
Mean effective pressure,	52·500
Revolutions,	106·69
Indicated horse-power,	134·490

Left.

Boiler pressure,	129·
Initial "	112 625
Cut-off in fraction of stroke,	·3880
Release " "	·8448
Terminal pressure,	37·000
Counter "	2·000
Exhaust closure,	·3265
Mean effective pressure,	58·208
Revolutions,	106·69
Indicated horse-power,	148·977

HAMILTON, No. 14

Right.

Boiler pressure,	135·
Initial "	122·344
Cut-off in fraction of stroke,	·3309
Release " "	·8192
Terminal pressure,	33·062
Counter "	10·875
Exhaust closure,	·3761
Mean effective pressure,	45·927
Revolutions,	170·21
Indicated horse-power,	187·698

Left.

Boiler pressure,	135·
Initial "	121·750
Cut-off in fraction of stroke,	·3880
Release " "	·8448
Terminal pressure,	37·250
Counter "	8·437
Exhaust closure,	·3265
Mean effective pressure,	51 794
Revolutions,	170·21
Indicated horse-power,	211·485

CINCINNATI, No. 35.

Right.

Boiler pressure,	98·
Initial "	79·312
Cut-off in fraction of stroke,	·3309
Release " "	·8192
Terminal pressure,	20·312
Counter "	2·875
Exhaust closure,	·3761
Mean effective pressure,	32·420
Revolutions,	208·33
Indicated horse-power,	162·170

Left.

Boiler pressure,	98·
Initial "	76·938
Cut-off in fraction of stroke,	·3880
Release in " " "	·8448
Terminal pressure,	21·375
Counter "	2·750
Exhaust closure,	·3265
Mean effective pressure,	33·936
Revolutions,	208·33
Indicated horse-power,	169·597

The general excellence of the engines from which these diagrams were taken will be apparent to engineers familiar with the indicator; at the same time it should be remembered that the valves were set entirely by the marks on the valve stems and guide bars.

The diagrams would be eminently creditable to many an automatic cut-off engine wherein the admission and cut-off are controlled by one valve or system of valves, and the release and exhaust closure regulated by another valve or system of valves, as in the Corliss engine; as it is, a single D slide valve, operated by a pair of eccentrics and a shifting link, performed all the functions of lead, port-opening, cut-off, release and exhaust closure.

The diagrams are worthy of study and emulation by builders of fixed cut-off engines; for the locomotive is simply a fixed cut-off engine, variable by hand. But so long as fixed cut-off engines are controlled in speed by the present system of governor which, as it were, throttles the engine in the act of respiration, but little improvement can be expected in the realized effect of valve motion.

The ordinary throttling governor is a nuisance that should not be tolerated by intelligent steam engine builders, for in the best form it robs the steam of *twenty per cent.* of its *vis viva* in effecting regulation, and the high relative economy of the standard automatic cut-off engine is entirely due to admitting steam at or near the boiler pressure and cutting off the quantity required to overcome the resistance, instead of wire drawing the steam until the mean pressure is equivalent to the resistance per square inch of piston.

In the locomotive engine, whilst the communication between the steam-dome and cylinder is not as free with early points of cut-off as in the automatic engine, the wire drawing is very much less than in throttling engines; and if a valve gear be devised for lococomotives which will produce a maximum opening of steam port for all points of cut-off; then for equal initial pressures and grades of expansion the economy of the locomotive and automatic engines (size of cylinder and speed of piston considered) would approximate.

For a given speed, given load, and given condition of track, the resistance is represented by a certain mean pressure per square inch of piston for a single stroke or for any number of strokes, with the elements affecting the resistance unchanged; and a nearer approximation of the initial pressure in the cylinder to that of the boiler, reduced friction in the port opening as the steam flows in, steam line declining less to the point of cut-off, earlier cut-off and higher grade of expansion, would improve the economy of performance of the locomotive without impairing its efficiency otherwise. It is possible to do all this without materially altering the existing valve gear

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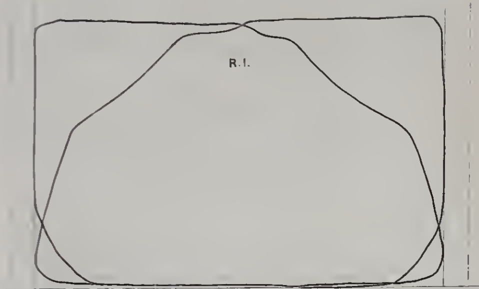
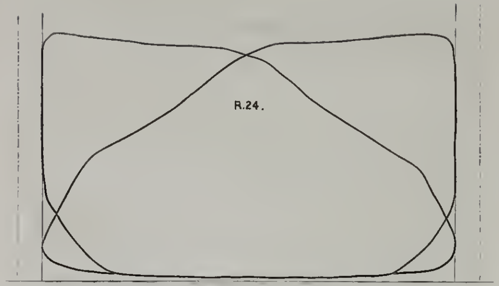
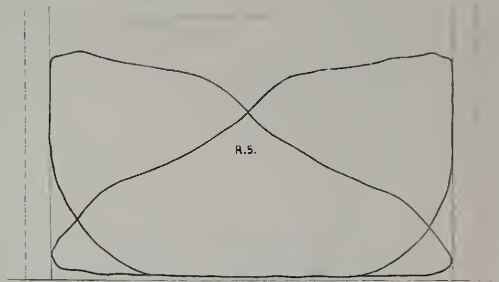
Imitation Gold.—Messrs. Maffre & Co. make an alloy which resembles gold in color and resistance to oxidation, by melting together in a crucible 800 grammes of pure copper, 25 grammes of platinum, and 10 grammes of tungstinic acid. When thoroughly melted, the mass is granulated by letting it run into water which contains 500 grammes (17·64 oz.) slaked lime, and 500 grammes of potash per cubic metre (35·32 cu. ft.). The granulated alloy is dried, re-melted and 170 grammes (6 oz.) of gold are added and thoroughly incorporated.—*Fortsch. der Zeit.* C.



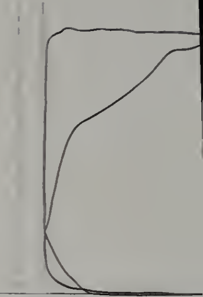
Diagrams No. 1. Right Engine. Twin Creek to Dayton. Rev's, 51·00.



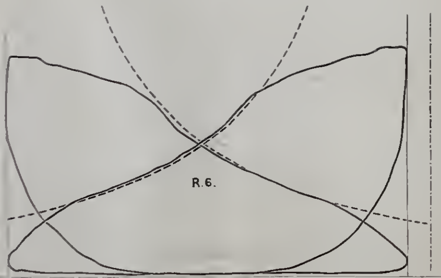
Diagrams No. 24. Right Engine. Cincinnati to Hamilton. Rev's, 67·51.



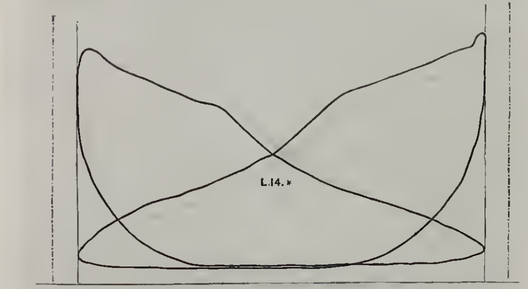
Diagrams No. 5. Right Engine. Cincinnati to Hamilton. Rev's, 120·02.



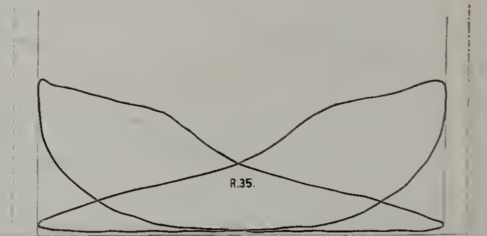
Diagrams No. 1. Left Engine



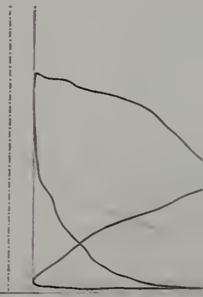
Diagrams No. 6. Right Engine. Cincinnati to Hamilton. Rev's, 106·69.



Diagrams No. 14. Right Engine. Hamilton to Twin Creek. Rev's, 170·21.

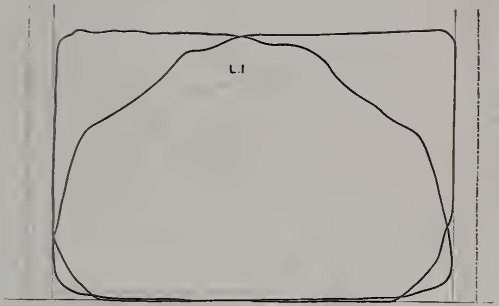


Diagrams No. 35. Right Engine. Cincinnati to Hamilton. Rev's, 208·33.

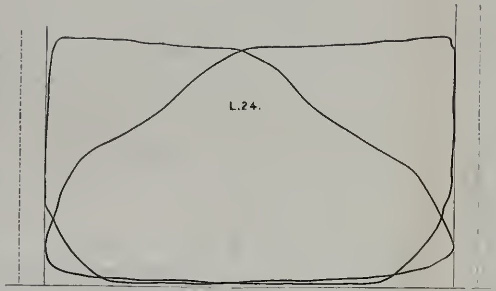


Diagrams No. 6. Left Engine

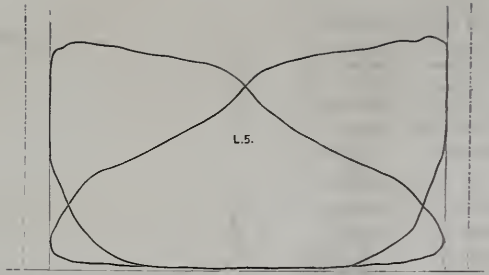
Rev's, 120·02.



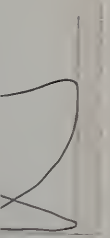
Diagrams No. 1. Left Engine. Twin Creek to Dayton. Rev's, 51·00.



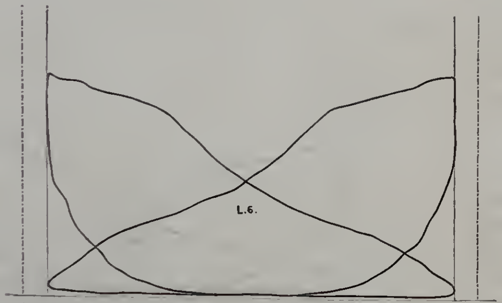
Diagrams No. 24. Left Engine. Cincinnati to Hamilton. Rev's, 67·51.



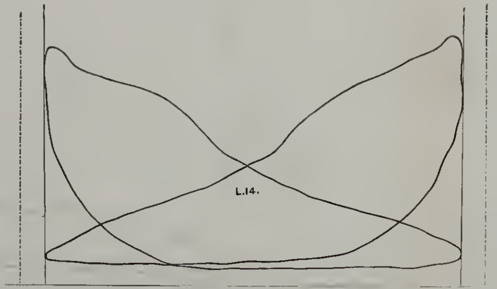
Diagrams No. 5. Left Engine. Cincinnati to Hamilton. Rev's, 120·02.



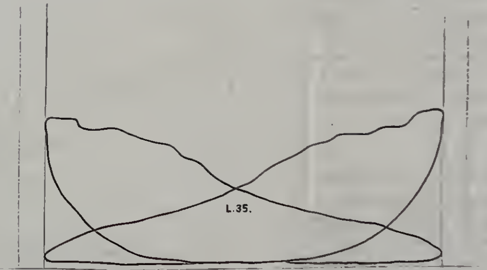
Rev's, [illegible]·33.



Diagrams No. 6. Left Engine. Cincinnati to Hamilton. Rev's, 106·69.



Diagrams No. 14. Left Engine. Hamilton to Twin Creek. Rev's, 170·21.



Diagrams No. 35. Left Engine. Cincinnati to Hamilton. Rev's, 208·33.

ON THE DRIVING POWER OF LEATHER BELTS.

By J. H. Cooper.

In the Journal of the Franklin Institute for November, 1878, is given a translation of Laborde's researches on the principle of the employment of belts for transmitting power.

The rules and tables forming part of this essay are restricted to driving belts which embrace but half the circumference of the pulleys, and for this reason they have a very limited application in practice. In order, therefore, to extend the usefulness of Laborde's work to the calculations of belts on pulleys of unequal diameter, which comprise much the greater number of cases, the "observations" of Mr. J. Heilmann are given below, a manuscript copy of which was kindly furnished to the writer by Mr. V. Steinlen, of Mulhouse.

"Observations on the friction of Belts upon the surface of pulleys and upon the width to give to Belts in special cases; communicated to the Industrial Society at the general meeting, May 27th, 1835, by Mr. Paul Heilmann, former student of the Polytechnic School.

"At the general meeting of the society, held on the 29th of May, 1833, Mr. Joshua Heilmann made you, in the name of the Committee on Mechanics, a report on the memoir of Mr. Laborde concerning the width of belts for transmission of power. In this report it is demonstrated that the table of Mr. Laborde cannot be applied except to the especial case of two pulleys of the same diameter, and consequently each one is enveloped half of its periphery.

"The inquiry made by the society in its department proved in effect that for such a special case the dimensions indicated by the table are good; but in other cases, and those which occur most frequently, the table will no longer answer.

"Having occupied myself in the search for the true laws relating to this theory, as yet but little applied in the arts, and believing to have solved the question, I arrived at the conclusions which I have the honor to submit to the society.

"Before speaking of the width of the belt it is necessary to consider and to study the friction of the belt upon the surface of the pulley; and to find the true expression of this friction we must necessarily consider the case of a pulley invariably fixed, and with the belt only movable; then admit that there be applied to the belt in the direction of its axis on the one side a force equal to the resistance and on the opposite side a force equal to the true motive power.

"In this manner we shall have the friction at the circumference, while if we had supposed the pulley movable on its axis, the results would only have shown the friction at the centre, arising from the pressure of the belt transmitted to the pulley.

"The science of applied mechanics gives the formula relating to this subject as follows: Calling

P, the resistance to be overcome,
e, the base of Naperian logarithms,
f, the coefficient of friction of leather upon cast iron,
R, the radius of the pulley,
S, the length of the arc of contact,

"This formula is written thus:

$$\text{Friction} = P\left((e)^{\frac{fS}{R}} - 1\right)$$

"In considering this formula it is easy to see that the friction diminishes rapidly when the radius increases, and that it augments rapidly with the length of the arc of contact, which explains a fact well known in practice.

"But it is to be noticed that the ratio $\frac{S}{R}$ is a constant quantity for the same angle, whatever may be the radius of the pulley, because the circumferences and consequently the arcs of a same number of degrees are proportional to their radii. It results, therefore, that the friction is the same for the same angle of contact whatever may be the radius of the pulley; or, in other words, that the length of the arc of contact should be proportional to the radius of the pulley to produce the same friction, all the rest being equal. A result of great simplicity.

"All this being considered, we see that the laws concerning the friction of curved surfaces are very different from those which relate to plane surfaces.

"Thus for plane surfaces the ratio of friction to the pressure is constant, whatever may be the extent of the surface, while with the cylindrical surfaces of which we speak, on the contrary, the ratio varies not with the extent of the surface, but with the proportional part of the circumference—with the number of degrees comprised in the arc of contact.

"It is easy to account for this difference.

"A plane surface under pressure is increased in size, the elements of surfaces which are added are all alike, and what is more important, are all equally pressed over the entire extent of the surface, each inch square, for example, receiving the same pressure.

"But let us consider a cylindrical surface pressed by a belt in the direction of pressure perpendicular to the axis, the pressure is not uniform; it is a maximum at that point where the tension of the belt is a maximum, since it is always the sum of the components in the direction of the radii of the tensions of the adjoining elements.

"This pressure diminishes towards the two extremities, and if an element of surface be added to the arc of contact the pressure will have another distribution on the surface, and the friction will change.

"This reasoning is not applicable to the case where the surface of the belt is increased in the direction of its width, because then any section whatever perpendicular to the length of the belt receives always the same pressure as before.

"It follows then, that:—

"The friction is the same for a same angle and a same tension, whatever may be the width of the belt.

"We see then, that the friction of a belt upon a pulley depends

1st. On the pressure or on the tension of a belt.

2d. On the angle of contact.

"And that the friction is independent

1st. Of the diameter of the pulley.

2d. Of the width of the belt.

"The friction is proportional to the pressure.

"According to the formula cited above I have constructed, with the aid of logarithms the following table, which gives the ratio of friction to pressure for any angle.

"The ratio of friction to pressure for leather upon plane surfaces of cast iron have been taken from the experiments of Mr. Morin; I have, however, verified the figures with a belt such as is in use in cotton mills.

"All the results relate to the cases where the machine passes from a state of rest to that of motion, the case in which the maximum of force is necessary.

"Now let us examine what part the breadth of the belt plays under these circumstances. It is evident after what has been said that the smaller the angle of contact is, the greater the strain which must be put upon the belt to transmit a given force; because the force it is possible to transmit by the pulley is always inferior, or at the most, equal to the friction produced upon the surface; if the resistance of the machine were greater, the belt would slip on the pulley. Now here the width of the belt serves no other purpose but to give to the belt a resistance—a strength sufficient to sustain this tension without stretching or breaking.

"This tension, and with it the width of the belt, must necessarily be in inverse ratio to the figures presented in my table. Consequently, in practice, we must employ the table of Mr. Laborde in the following manner, modified by what I have the honor to present, a method by which one can convince himself that the widths indicated by Mr. Laborde may sometimes be increased in a tenfold proportion, or be reduced to a third, according to circumstances.

"In the first place, in practice, we should determine the number of man- or horse-power, the maximum force to be transmitted by the belt and the speed at which it is to be driven, which will indicate a certain breadth in inches given by the table of Mr. Laborde. Then measure, in degrees, on the surface of the smaller pulley, *i. e.*, the least enveloped, the arc of contact with the belt. Then find in my table the figure which expresses the ratio of friction to the pressure corresponding to an angle of 180°, which served as the basis of construction of Mr. Laborde's table; then multiply the breadth found by this figure, and divide the product by the ratio of friction to the pressure corresponding to the angle of contact found.

"Example: Required, the width of belt to transmit a force of 2 horse-power with a speed of 500 feet per minute, the angle of contact of the smaller pulley being 120°.

"I find in the table of Mr. Laborde 6 inches, which I multiply by $\frac{4670}{2911}$: I have then 9 inches and 7 lines.

"Example: 3 man-power, speed 400 feet per minute, angle 240°. I find 1 inch and 9 lines, which I multiply by $\frac{4670}{6669}$, and I have for the result 1 inch and 3 lines.

"I will add, however, that one must not forget that the weight of the belt and its friction when it is crossed are also factors to be introduced into the formula, if rigorous exactness is to be attained. However, it is easy to see that their figure is too small to embarrass the practical mechanic, who in all cases should not hesitate to give an excess to the width above that which proceeds from the calculations here given.

Degrees.	Fraction of the Circumference.	Ratio of Friction to the Pressure.	Degrees.	Fraction of the Circumference.	Ratio of Friction to the Pressure.
30	$\frac{1}{12}$	0·0660	$22\frac{1}{2}$	$\frac{1}{16}$	0·0491
60	$\frac{2}{12}$	0·1363	45	$\frac{2}{16}$	0·1005
90	$\frac{3}{12}$	0·2112	$67\frac{1}{2}$	$\frac{3}{16}$	0·1545
120	$\frac{4}{12}$	0·2911	$112\frac{1}{2}$	$\frac{5}{16}$	0·2706
150	$\frac{5}{12}$	0·3763	135	$\frac{6}{16}$	0·3330
180	$\frac{6}{12}$	0·4670	$157\frac{1}{2}$	$\frac{7}{16}$	0·3933
210	$\frac{7}{12}$	0·5674	$202\frac{1}{2}$	$\frac{9}{16}$	0·5390
240	$\frac{8}{12}$	0·6669	225	$\frac{10}{16}$	0·6145
270	$\frac{9}{12}$	0·7769	$247\frac{1}{2}$	$\frac{11}{16}$	0·6937
300	$\frac{10}{12}$	0·8941	$292\frac{1}{2}$	$\frac{13}{16}$	0·8642
330	$\frac{11}{12}$	1·0190	315	$\frac{14}{16}$	0·9551
360	$\frac{12}{12}$	1·1522	$337\frac{1}{2}$	$\frac{15}{16}$	1·0515

New Voltaic Battery.—M. A. Heraud uses chlorohydrate of ammonia and calomel. When the circuit is closed the chlorohydrate of ammonia, in the presence of zinc, forms a chloride of zinc with the transference of ammonia and hydrogen to the positive electrode. The hydrogen reduces the calomel, yielding metallic mercury, chlorohydric acid, and consequently chlorohydrate of ammonia. As long as there remains any of the calomel about the positive electrode the chlorohydrate of ammonia will be regenerated. In a battery of nine elements the intensity was ·73 at the end of 227 days, and ·50 at the end of 984 days, the primitive intensity being 1. When compared to sulphate of copper the mercury gave an intensity of 1·4512 at the beginning, and 1·0749 after six months' use.—*Comptes Rendus.* C.

ON THE ACTION OF FATTY MATTER IN STEAM-BOILERS.

By G. Pereyra, Mining Engineer.

Translated from the *Annales des Mines* of 1878, by Chief Engineer Isherwood, U. S. Navy.

For many years past the water of condensation of the exhaust steam from steam-engines has been used for feeding boilers. The practice, though possessing advantages, among which is economy of fuel, is not without drawbacks, for numerous accidents have attended it, which have been attributed to the fatty matter contained in this water of condensation.

The practice may be divided into the two cases of the exclusive use of the water of condensation, and of the use of that water mixed with spring or river water. The first has been made the subject of a recent communication from Mr. Hétet to the Academy. That scientific chemist points out deep corrosions of the boiler and the formation of black dense deposits, mixed with oxide of iron, which adhered strongly to the metal and caused it to be overheated or burned. He also points out that this corrosion and its resulting accidents could be avoided by neutralizing with lime the fatty acids contained in the feed-water. The process is excellent, but only on the condition that the water thus treated is separated afterwards by decantation or better still, by filtration from the lime-soap thus formed. The facts to be given in this paper will be found to fully justify this condition.

The mixing of the water of condensation with spring or river water causes greasy-lime deposits, whose effects on boilers are still the subject of numerous controversies. Some engineers deny the injurious influence of these deposits, considering them no worse than ordinary scale; while others attribute to them the most pernicious action. Another class entertains the intermediate opinion, that in certain cases and with certain kinds of water, fatty matter in the boiler can be productive of serious damage.

I am of this latter opinion, for observed facts show both the former ones to be too absolute. But in what cases, and with what waters, has the fatty matter a pernicious action? I think these questions have not yet been answered. I neither pretend to specify all the possible cases, nor to formulate a theory invulnerable to criticism; I limit myself to describing the results of some observations and experiments, and to stating the conclusions which I believe I have logically drawn from them, submitting the whole to the appreciation of specialists.

Properties of greasy-lime deposits.—From a much damaged boiler I gathered a deposit of the following composition:

Carbonate of lime,	83·747
Carbonate of magnesia,	2·707
Sulphate of lime,	2·042
Lime in excess,	3·137
Organic matter,	2·240
Fatty matter,	1·010
Oxide of iron,	2·225
Silica,	1·900
Water,	0·800
Not ascertained and loss,	0·192
Total,	100·000

This pulverulent deposit is of a greyish color, adheres but slightly to the heating surfaces of the boiler, and has the peculiarity of not being made wet by cold water, on the surface of which it floats, but during ebullition it is promptly made so and mixed with the liquid.

On the same fire I placed two identical vessels, each containing the same quantity of water, to which, in one, I added a quantity of the above greasy-lime substance. The ebullition in the two vessels was very different, being tranquil with the pure water and tumultuous with the water containing the greasy-lime substance. The latter liquid had a singular appearance: it had become an *emulsion* with a considerably increased volume, being comparable in all respects to milk in violent ebullition. The experiment, which was several times repeated, showed the emulsion to be more intense, other things equal, as the quantity of the greasy-lime substance was greater; but I found the proportion of about one-half of one per centum was sufficient to initiate the phenomenon.

The ebullition of water, whether with ordinary calcareous deposits, or containing different salts, such as the carbonate and sulphate of lime, the carbonate of magnesia—even in the calcined state—sulphate of baryta, etc., either separately or together, produced no similar emulsion. Finally, the same greasy-lime substance, on being calcined at a high temperature, lost all its typical qualities: it could be made wet with cold water, and no longer produced any emulsion on ebullition.

The emulsion-making property of this greasy-lime substance must, therefore, be necessarily attributed to the fatty matter it contained; for that the different organic matters which disappeared with the grease by the calcination could have any influence on that property is not supposable, because the nature of these matters is evidently the same as that of the organic substances in ordinary boiler-scale, which produces no emulsion.

I likewise made different analogous experiments with the greasy-lime substance, in which the proportion of grease varied from sixteen to twenty-five per centum, the kind of mineral matter with which it was combined remaining always the same, whether of carbonate and sulphate of lime, or of carbonate of magnesia, or of silica, etc., and I observed the same phenomenon of emulsion except in the following three cases:—

1. That of a deposit containing seventy-six per centum of fatty matter, taken from the hot well of the engine of a sugar manufactory.

2. That of a deposit containing forty-four per centum of fatty matter, taken from a boiler supplying steam to a condensing engine.

3. That of a deposit taken from a part of a boiler which had been exposed to the action of the atmosphere for more than a year. (The greasy-lime substance, on the contrary, taken from a sheltered part of the same boiler, and therefore not exposed to the action of the atmosphere, was emulsion-making.)

These three deposits could be made wet by cold water.

Finally, I made other experiments of the same kind on some greasy-lime substances that were very rich in fatty matter (from thirty to seventy-five per centum). The analyses of these substances disclosed a considerable proportion of oxide of iron, indicating an intense corrosion of the boiler-plates on which they had been deposited. When the substances rich in fatty matter were pulverized they floated on water, but by ebullition the powder soon agglutinated, sunk, and stuck to the bottom and sides of the containing vessel.

But when the substances poor in fatty matter were pulverized the powder did not, on the contrary, agglutinate, but if left, after having produced an emulsion, to sink to the bottom of the containing vessel, it *did not adhere*, although allowed to remain quiescent for several days. When the liquid was again heated the emulsion was reproduced.

A last experiment, which appeared interesting to me, consisted in making in the laboratory an artificial greasy-lime substance by the vaporization of limy water to which fatty matter had been added. I took the limy water of several factories where emulsion-producing substances had been found, and after ascertaining the quantity of solid matter in solution, I added the necessary quantity of fatty matter in the proportion, approximately, of one-half of one per centum. I discovered that the substances thus formed *in free air* did not possess the emulsion-making property.

This experiment tends to prove, in my opinion, that pressure is necessary to the production of an emulsion-making combination of lime and fatty matter; and it explains the previously mentioned non-emulsion making property of the greasy-lime deposit taken from the hot-well, in which the pressure is but little greater than that of the atmosphere. It also explains the non-emulsion making property of the second deposit containing forty-four per centum of fatty matter. I could not possibly know the pressure under which this last deposit was formed, but as the engine was a condensing one the supposition of a low pressure in the boiler is probable.

It does not appear to me that the composition of the water has the influence on the properties of the greasy-lime deposit which some engineers believe. The different deposits I have examined contained the ordinary elements of spring or river water, but in variable proportions, it is true. If there were any variation in the properties of these deposits it was solely due to the more or less quantity of fatty matter they contained, and to the circumstances which accompanied their formation. I sum up these properties in the following table:

Deposit with fatty matter in strong proportion.	Corrosive property.	Adherence to the metal.
Deposit with fatty matter in feeble proportion.	Formed under low pressure.	Deposit made wet by cold water. Same properties as ordinary boiler-scale.
	Formed under high pressure.	Deposit not made wet by cold water, is made so by hot water, and produces an emulsion by ebullition, which is not adherent to the metal.

Action on the boiler of greasy-lime having a small proportion of grease.—The first boiler accidents attributed to the greasy-lime substance occurred in Germany in 1864; and later, in 1867, Mr. Farcot made an interesting communication to the Society of Civil Engineers on the injuries to a tubular boiler having 1722 square feet of heating surface, erected in the factory of Pont-Remy. These injuries were manifested by large leaks along the upper seams of the interior furnace, and after prolonged investigation, they were attributed to the greasy-lime deposit. By the side of this boiler several combined cylinder boilers were fed with the *same water*, without injury, and this fact is worthy of remark.

From that time such accidents have become frequent; occurring, notably, in a great number of sugar manufactories, and especially to tubular and semi-tubular boilers. In tubular boilers the seams of the inner furnace were ruptured and the stays broken, while in semi-tubular boilers, the plates which received the hottest impact of the flame were ruptured, the fracture following the first circular seam.

These accidents were attributed to the greasy-lime deposit alone, because it was remarked that from the moment the formation of the deposit was prevented, the accidents ceased. The explanation adopted up to the present time is that the greasy-lime substance did not become wet, and being deposited upon the boiler-plates, isolated them from the water, in consequence of which they became overheated and the accidents resulted.

The overheating of the boiler-plates is not to be doubted, for the nature of the injuries prove it, as well as the presence of carbonized matter in the deposit; but, in my opinion, the explanation is erroneous, for the deposit does *not adhere to the boiler-plates*, and further, it *is made wet by hot water.* How can such a theory explain the absence of injury, which I have established to be the fact in other cases, to combined cylinder and semi-tubular boilers fed in the same manner as similar ones which were injured? The emulsion-making property of the greasy-lime substance, of which no account has previously been taken, must here be brought forward, and the explanation of the phenomena can easily be deduced from it.

I remark, at the beginning, that for a boiler to operate properly, it is necessary, in the first place, that the quantity of heat furnished by the furnace, in a given time, shall not exceed the quantity of heat which the metal of the plates can transmit in the same time to the liquid to be vaporized; and in the second place, that all the heat which traverses this metal shall be integrally absorbed by the liquid.

If this equilibrium is destroyed, either by excess of heat furnished by the furnace or by reason of a diminution in the heat-absorbing power of the liquid to be vaporized, there necessarily results an accumulation of heat in the metal of the boiler plates, producing a considerable elevation of their temperature. This overheating will occur especially in those plates which are acted on by the radiant heat (direct heating surface), in the plates of the connecting pipes of combined cylinder and semi-tubular boilers, and in the tube-plates and crown-sheets of furnaces in tubular boilers, the effect being the production of abnormal dilatations. On the withdrawal of the fire, and even on the diminution of its intensity, the overheated plates cool first, so that during the ordinary use of the boiler its plates are subjected to a succession of dilatations and contractions which at length change the molecular constitution of the metal, strain the seams and end by causing leaks at the rivets and fractures at the weakest places.

Now, in my opinion, the equilibrium which characterizes the normal action of a boiler is broken when the emulsion-making greasy-lime substance begins to form; for the mixture of steam and water which constitutes the emulsion produced by that substance, possesses a less heat-absorbing power than water. The overheating of the plates should now commence, and from that moment accidents are possible.

The extent of the injuries are probably governed by the quantity of the substance present, on the one hand, and by the time during which it acts on the other. In fact, the strength of the emulsion, and consequently the heat-absorbing capacity of the mixture of the substance and water, depend on the quantity of the substance. The influence of the duration of its action appears evident to me, for, in the case of a boiler in ordinary use, the heating and cooling are periodic, so that the expansions and contractions are numerous just in proportion to the time; consequently, as the substance acts longer during a longer time, the molecular changes produced in the metal must be correspondingly greater.

I need scarcely add that for a determined value of the preceding elements, the quantity of heat furnished by the furnace in a given time remains below a certain maximum, the equilibrium of the normal action of the boiler will not be overthrown, in which case overheating could not occur, but the production of steam would be less.

It is conceivable that for each boiler in which the emulsion-making greasy-lime substance is produced, there exists between the quantity of heat furnished or quantity of combustible consumed, the quantity of the substance and the length of time during which it acts, a proportion necessary and characteristic of that boiler as regards its sensibility to the action of the substance. It is also conceivable that when, in practice, one of these three elements passes the limits determined by that proportion, a serious accident will happen, whilst below that limit no accident is to be feared.

Is not this the correct theory for the explanation of the following facts? The semi-tubular boilers containing 1722 square feet of heating surface, which belong to a sugar manufactory in the Department of the Aisne, were all fed with a limy water mixed with greasy water of condensation. They received no injury during the first year, but during the second year they all fractured in an identical manner at the first circular seam.* In a factory in the suburbs of Paris, some combined cylinder boilers, containing 775 square feet of heating surface, have been in daily use for several years, with emulsion-making greasy-lime deposits, but without injury.

The particular sensibility of any boiler to the action of these deposits is not known, as observations in that respect have not been sufficiently numerous, and direct experiments are difficult to make; nevertheless, I believe we may predict that one type of boiler will be more sensitive than another, from the following considerations.

Among the boilers commonly employed in factories, there may be discriminated those of small heating surface, such as the combined cylinder boilers in which that surface rarely exceeds 700 or 750 square feet; and those of large heating surface, such as the tubular and semi-tubular boilers, in which that surface is often 21,500 square feet. I shall adopt this general classification, without deeming it indispensible to fix the exact limits of each category.

Now, in any boiler, the quantity of combustible burned in a given time should be proportional to the heating surface; but, for an economic vaporization, the grate surface should also be proportional to the quantity of combustible burned, and consequently to the heating surface. Various practical considerations however, and among others, the difficulty of maintaining and cleaning the fire on large grates, has led boiler makers to limit the dimensions of the furnaces, from which may be concluded that in boilers with large heating surfaces there is necessarily burned considerable quantities of combustible per unit of surface of grate.

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* After these accidents, the use of limy water was abandoned, and the boilers have been fed with distilled water, since which time no further accidents have happened.

The heat furnished to the *direct* heating surface can be integrally absorbed by the liquid to be vaporized only to the extent of the heat-absorbing power of the latter. Now, the emulsion-making greasy-lime substance has exactly the effect of reducing this heat-absorbing power, rendering it conceivable, in view of the great quantity of combustible burned, that a small quantity of the greasy-lime substance may be sufficient to destroy the equality between the quantity of heat furnished and the quantity of heat absorbed, and to cause, consequently, overheating of the boiler-plates together with the accidents which accompany it. Therefore, the boilers with large heating surfaces are more sensitive to the action of the greasy-lime substance than those with small heating surfaces.

Other facts confirm this: Before the introduction of tubular and semi-tubular boilers into factories, accidents from the greasy-lime substance were very rare, and even its existence was hardly suspected. For example, in the factory at Pont-Remy, the combined cylinder boilers having a small heating surface, acted very well, although fed with a mixture of limy water and greasy water of condensation; but, on the contrary, a tubular boiler of 1722 square feet of heating surface, fed in the same manner, was seriously injured. At the present time, there is in a factory a combined cylinder boiler, containing 775 square feet of heating surface, which works well, although the greasy-lime substance is constantly produced in it. Another factory, on the contrary, has tubular boilers, containing 1722 square feet of heating surface, which have all suffered accidents from the greasy-lime substance.

To sum up: When fatty matter is introduced into a boiler, it forms greasy-iron or greasy-lime deposits, which act on the metal of the boiler in a different manner, according to the more or less fatty matter in them; and according as the pressure under which they are formed is more or less elevated. If the deposit is very rich in fatty matter, it is corrosive, adherent, and causative of overheating at the places of adherence. If the deposit is poor in fatty matter and was formed under a low pressure, it acts simply like ordinary boiler-scale; but, if it be formed under a high pressure, its action is entirely special, and it can cause accidents by overheating. In the case of any given boiler, the probabilities of these accidents depend on the quantity of the deposit, on the time of its action, and on the quantity of combustible burned. If these three elements exceed certain limits, a serious accident will happen; but, below these limits, the boiler can function *without danger.* Finally, a boiler with large heating surface is more sensitive to the action of this deposit than one with small heating surface.

ON THE INITIAL EFFECT OF THE EARTH'S ROTATION ON THE FREE PENDULUM.

By Thomas William Tobin,
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The pendulum defined.

Let the plane of vibration of a pendulum be represented by BAC, Fig. 1. For the purpose of demonstration, let A be considered as the point of origin to which any alteration in the plane BAC is to be referred. AB is the axis of vibration. B, a fixed point about which the vibration Cc occurs.

Fig. 1.

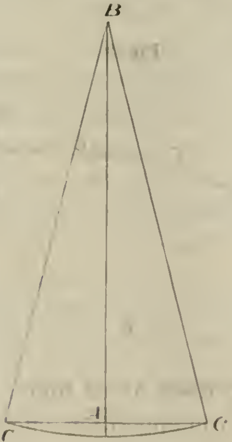
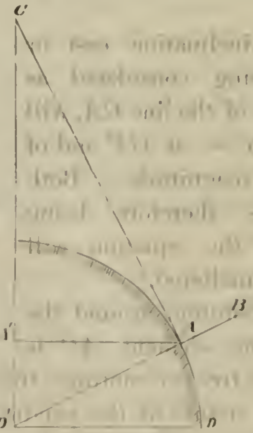


Fig. 2.



Any deviation of the plane BAC may be resolved into the elements AB and AC.

THE ANGLE OF THE EARTH'S DEVIATION.

We will first consider the effect of the earth's revolution upon the element AC, the plane of vibration being north and south, the point A as represented in Fig. 2 and point C perpendicular to AB in the axis of the earth's rotation. The length of AC will remain constant. In Fig. 3 draw CA and the arc AF equal to the space passed through by the point A in a given time, say 24 hours, AF will then be equal to the circle of latitude at A. The line AC will be at CF. Draw FG parallel to AC. It is evident the angle at F will represent the angle of deviation that the earth has undergone in relation to the element AC.

To find the value of the angle F or C its equal:

(Fig. 2) $$\text{As } CA : A'A :: AD' : A'D'$$

$$\text{or } CA : \text{cos. lat.} :: \text{rad.} : \text{sin. lat.}$$

$$\therefore CA = \frac{\text{cos. lat.}}{\text{sin. lat.}}$$

(Fig. 3.) On CA lay off CL equal to the cosine of latitude (AA') and draw the circle LL'.

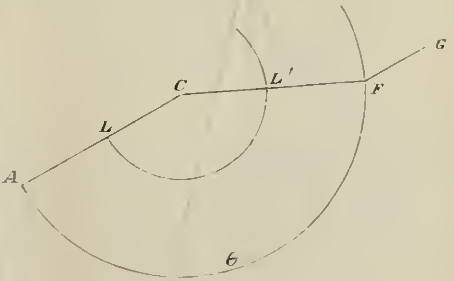
$$\text{Now circle } AF : \text{circle } LL' :: CA : CL$$

$$\text{and circle } AF : \text{arc } AF :: 1 : \theta$$

$$\therefore CA : CL :: 1 : \theta$$

$$\text{and } \theta = \frac{CL}{CA} = \frac{\text{cos. lat.}}{\frac{\text{cos. lat.}}{\text{sin. lat.}}} = \text{sin. lat.}$$

Fig. 3.



Any inclination east or west being considered as + or — of the line CA, will be + or — at GF and of equal magnitude. Both members therefore being satisfied the equation will remain unaltered.

In revolution around the earth the element AC is perfectly free to continue this relation to itself at all times. In the physical nature of the pendulum there is no opposition offered to the several points A and C. Traversing equal spaces in equal times, they must retain the same relation to each other. Assuming this argument to be true, the formula is not an approximation but absolute.

But the element *AB* in revolution suffers a constant alteration by gravity and therefore resistance.

THE LATERAL FORCE.

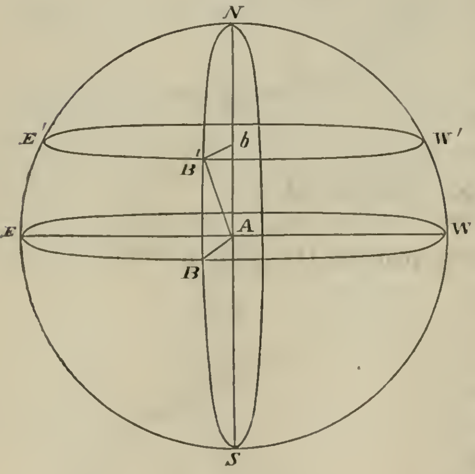
As the element *AC* in tho revolution of the earth remains unaltered, the deviation of the element *AB* will indicate the whole resistance encountered by the plane *BAC*.

Its magnitude will be represented by

(*a*) . . . . The quantity of motion or momentum in the plane *BAC*. Let this be taken as a constant.

(*b*) . . . . The amount of lateral deviation of the point *B* in relation to *AC*.

Fig. 4.



In Fig. 4 the point *A* is fixed in relation to the earth, point *B* in one revolution of the earth would describe the circle *EW*. If the element *AC* is situated N. and S., the lateral resistance of point *B* may be estimated by the circle *EW* or by its radius *AB*. As this is the greatest circle that can be described by *B* and the lateral resistance directly opposed to the direction of *B* the maximum, we may designate the resistance, *r*, encountered in one revolution as

(1) . . . . the plane *N* and *S*. $r = \text{rad.} \times 1$.

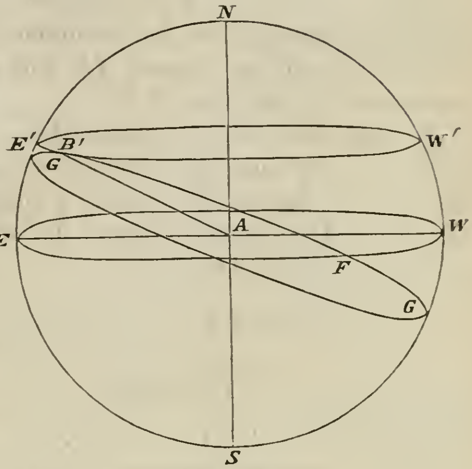
If the plane is situated as at *E W*, the point *B* being at all times in the same plane, the lateral resistance will be 0 and we have

(2) . . . . The plane *E* and *W*. $r = \text{rad.} \times 0$.

The resistance to point B' in plane *N S* will be measured by the circle $E'W'$, and as the line AB' must always, by the influence of gravity on the axis of the pendulum make with the earth's axis an angle equal to NAB', the circle $E'W'$ may be represented by cos. lat., $B'b$; for the position on the earth's surface where the pendulum is placed.

Next in regard to point B' let the plane be $E\,W$ as in Fig. 5, the lateral resistance of B' through the circle $E'W'$ will be the normal component of which the space described by B' in revolution is the resultant. The other component is in plane GG and therefore inert.

Fig. 5.



In Fig. 6 $B'A$ is the plane of inclination, $B'W$ the line of direction. $B'W$ is therefore resultant of which $B'm$ and $B'n$ are components.

As $B'm : B'W ::$ sin. lat. : rad.

$\therefore B'm = B'W \times$ sin. lat.

and the lateral resistance of point B' may be expressed

(3) . . . . the plane N and S. $r =$ cos. lat. × 1.

(4) . . . . the plane E and W. $r =$ cos. lat. × sin. lat.

We have now to consider the plane BAC in any position.

Fig. 6.

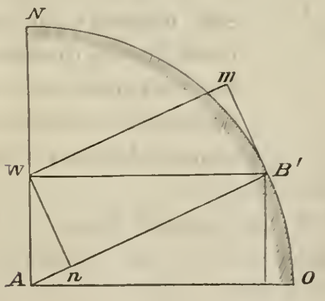
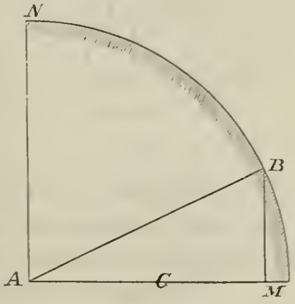


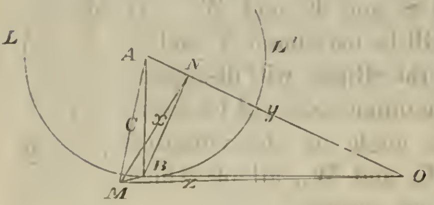
Fig. 7.



THE PLANE OF INCLINATION.

The normal component $B'm$, or amount of resistance encountered by the point B', is determined by the angle $AB'W$ or its equal $B'AO$. It is evident from the foregoing reasoning that any point in the plane GG', Fig. 5, as for example F, will have resistance, r, measured by the circle described by it or the radius of that circle, multiplied by the normal component of the lateral resistance to that plane. It is then necessary to ascertain the angle made by any plane passing through A with the plane of the earth's rotation, EW, and the position of the point B' in that plane, to find the value of r.

Fig. 8.



In Figs. 7 and 8 let c be the cosine of latitude, BM the sine of latitude, BOM the given angle of the plane of vibration at B from E and W, LL' the circle of latitute at B. Join AO and draw BN perpendicular to AO. Join AB and NB. BNM will be the angle of inclination of the plane ABO to the plane AMO. It is required to find this angle.

$$c : y :: x : z$$

$$x = \frac{c\,z}{y} = \cos.\ d \times \cos.\ \text{lat.}$$

in which d = azimuthal angle of the plane of vibration from E and W and x = cosine of angle of inclination of plane of vibration to plane of the earth's rotation.

Substituting this value of d in Equations (1), (2), (3) and (4), the general formula for the initial lateral resistance of point B will be

(5) . . . . $r = \cos.\ \text{lat.} \times \sqrt{1 - (\cos.\ d \times \cos.\ \text{lat})^2}$

while the deviation of C is

(6) . . . . $\theta = \sin.\ \text{lat.}$

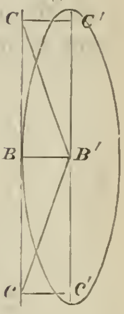
THE EFFECTIVE RESISTING FORCE.

Let us now consider the application of this resisting force in the performance of the pendulum. It has been argued that an augmentation of the angle θ arises from it and observed results of this angle of deviation are in excess of the calculated data. Thus at New Haven, lat. 41° 18½′ N., the calculated angle was 9·928° per hour (Lyman) observed angle, 9·97. If this theory were true, our formula predicts a deviation when the pendulum vibrates N. and S. at the equator! Is observation in accordance with this fact?

A more rational explanation seems to be furnished in the elliptical motion of the pendulum after starting.

In Fig. 9 let Cc represent the original vibration, at the end of given time let the lateral resistance be indicated by BB'. The vibration about B' having regard to the persistence of the plane Cc will assume the ellipse whose centre is at B' and foci at C'' and c'.

Fig. 9.



If this theory is true we have these ellipses in the same latitude of different magnitudes in the same time when the pendulum vibrates N. and S. and E. and W. At the equator the conjugate axis will be maximum N. and S. and 0 E. and W. At the poles the ellipses will disappear. In general, the magnitude of the minor axis will be determined by the latitude and the angle of the vibrating plane of the pendulum from E. and W., all of which may be inferred from the foregoing formula.

ACCIDENTAL ELLIPTICITY.

The foregoing results are based upon the supposition that the pendulum at starting receives an impulsive force, applied at the centre of oscillation, while the pendulum is at rest in its axis of vibration, $A\ B$, Fig. 1. Practically, this is never achieved in experiment, and an accidental lateral force is the result. The detention of the pendulum out of the axis of vibration, the method usually employed in starting the experiment, may be determined in the tangentral force of Prof. Stanley. But the most fruitful sources of accidental ellipticity are probably owing to the imperfection of the point of support and the torsion of the suspending medium. In the latter method of starting, unless the point of detention, the centre of oscillation and the axis of vibration are in a common plane, ellipticity is inevitable.

The best results I have obtained were by using the rigid pendulum and clamping the cross-piece described in the "Sine Pendulum," JOUR. FRANKLIN INST., vol. civ, p. 418, so as to confine the vibration to one plane. On releasing the cross-piece, this plane of vibration was free, or nearly free, from accidental disturbing causes.

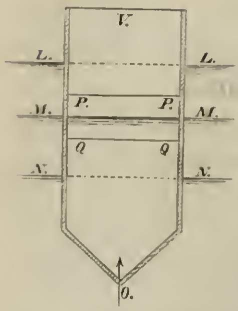
Coloring to Milk.—It appears that milk is dyed according to the food given to the cow. If fed with *Anchusa tinctoria* they yield a blueish milk, if with *Rheum palmatum* a yellowish, and if with madder or bed straw (*Galium*) a reddish.—*Chem. News.*

ON THE MEASUREMENT OF TIDAL HEIGHTS.

A METHOD PROPOSED TO ELIMINATE THE ACCIDENTAL ERRORS OCCASIONED BY WAVE-MOTION IN TIDAL OBSERVATIONS, AND TO OBTAIN, UNAFFECTED BY SAID ERRORS AND AT GIVEN INTERVALS OF TIME, THE REAL TIDAL HEIGHTS OF THE SEA LEVEL FROM A GIVEN PLANE TO WHICH SAID OBSERVATIONS ARE REFERRED.

By L. d'Auria.

Fig. 1.



Let a vessel *V* (Fig. 1) be immersed and fixed in the sea, and the water entering it through a small orifice *O*, placed at its bottom. The sea surface being affected by wave-motion, it will oscillate on the outside of said vessel vertically; and if the horizontal lines *LL* and *NN* represent, respectively, the superior and inferior limits of the oscillation there, the velocity of the sea surface on the vessel will be equal to zero, and it will be equal to its maximum when said surface reaches its middle position *MM*. Inside of the vessel *V* the surface of the sea oscillates too, and whatever may be its oscillation, its middle position will coincide with *MM*. Indicating by the horizontal lines *PP*, *QQ*, respectively, the superior and inferior limits of the internal oscillation, the velocity of the sea surface inside of the vessel will be equal to zero when in those limits, and will be equal to its maximum when in the middle position *MM*. But as this velocity depends upon the head of water on the orifice *O*, when this is equal to zero, or when the external level is in coincidence with the internal one, the velocity of the latter will be equal to zero; therefore, this coincidence will take place in the lines *PP*, *QQ*, and it will be easily understood that when the coincidence takes place in *PP*, the external level must be in its descending phase, and it must be in its ascending phase when the coincidence takes place in *QQ*.

From the foregoing results that the head of water on the orifice *O* must be equal to its maximum when the internal level reaches its middle position *MM*. Now supposing the external level in coincidence with the internal one in *PP*, or in *QQ*; and representing by t the period of the waves, in $\frac{1}{4}t$ the internal level will pass from PP or QQ to MM; and in the same time, it is evident, the external level will pass from PP or QQ, respectively, to a position which will be above NN or below LL; therefore, the maximum head of water on the orifice O will be less than the distance between MM and LL or between MM and NN, which we indicate by r; and the maximum velocity of the internal level will be less than

$$\frac{s\mu}{S}\sqrt{2gr};$$

in which S is the area of the cross-section of the vessel V; s, the area of its orifice O; and μ the co-efficient of efflux for said orifice.

Taking for mean velocity

$$\frac{1}{2}\,\frac{s\mu}{S}\sqrt{2gr}$$

and putting

$$\frac{s\mu}{S}=m$$

the amplitude of oscillation of the internal level will be

$$x=\tfrac{1}{4}tm\sqrt{2gr}.$$

But from the Hagen's experiments on sea waves results

$$t=\pi\sqrt{\frac{2r}{g}}$$

therefore

$$x=\tfrac{1}{2}\pi m r.$$

The weather and the situation in which tidal observations are taken are such that it is quite enough to assume $r = 0^{m}, 50$, or $2r = 1^{m}, 00$, as the maximum amplitude of the waves during the observations. Taking $m = \frac{1}{2225}$, will be $x = 0^{m}, 00035$; and with these data we can consider the internal level as being quite unaffected by wave-motion.

Now to investigate the movements of this level by the tide effect, we can suppose indifferently the surface of the sea as being unaffected by wave-motion, because this supposition does not change at all the conditions of the water in the vessel V; but we cannot say the internal level moves the same as the external one, just for the same reasons the effect of wave-motion has been eliminated in said vessel; and we can see *a priori* that during the flow the internal level will be below the external one, and during the ebb the external will be below the internal.

Let l be the distance between these levels at a given instant, and w the velocity of the external level; the variation of l in the following instant will be

$$dl = dt\,(w - m\,w - m\sqrt{2gl}\,)$$

from which

$$w\,(1 - m) - m\sqrt{2gl} = \frac{dl}{dt} = u\,;$$

and

$$l = \frac{[w\,(1 - m) - u]^2}{2gm}$$

in which u represents the relative velocity of one level in reference to the other.

The velocity of w becomes equal to zero at the high and low water, therefore, at a certain intermediary position of the internal level, it must be equal to its maximum. Now if we indicate by H the difference of heights between high and low water, and by T the time between these positions, the mean value of w will be

$$w_0 = \frac{H}{T}\,;$$

and the maximum value of w will be approximately

$$W = \frac{2H}{T}.$$

As the maximum value of l corresponds to $w = W$ and $u = 0$, it will be

$$L = \frac{W^2\,(1 - m)^2}{2gm^2} = \frac{2H^2\,(1 - m)^2}{gm^2\,T}.$$

The maximum value of u is approximately

$$U = \frac{4L}{T} = \frac{8H^2\,(1 - m)^2}{gm^2\,T^3}\,;$$

therefore, the value of l, which corresponds to $w = 0$, will be not greater than

$$l_0 = \frac{32H^4}{g^3m^6T^6}.$$

If this value is so small as to be neglected in calculations, we can assume that for $w = 0$, also $l = 0$; and in such case the high and low water of the internal level will coincide in heights and times with the high and low water of the external level. For intermediary positions of the sea level, the value of l will be then

$$l = \frac{w^2\,(1 - m)^2}{2gm^2} \qquad . \quad . \quad . \quad . \quad (1)$$

in which w can be changed for the velocity of the internal level, because the latter being

$$wm + m\sqrt{2gl};$$

it becomes w when, instead of l, we substitute the value (1).

The conclusion will be to take tidal observations from the level of the sea in the vessel V, to avoid the accidental errors occasioned by wave-motion. These observations, which we indicate by

$$h_0,\ h_1,\ h_2,\ h_3,\ \ .\ \ .\ \ .\ \ .\ \ h_n,$$

registered in order of succession and taken at equal and small intervals of time ∂t, between two consecutive passages of the moon through the meridian, will give us the value of w corresponding to each of them, by

$$w_0 = \frac{h_n - h_0}{\partial t};\ w_1 = \frac{h_0 - h_1}{\partial t};\ w_2 = \frac{h_1 - h_2}{\partial t};\ .\ \ .\ \ .\ w_n = \frac{h_{(n-1)} - h_n}{\partial t};$$

and after the corrections

$$l_0 = \frac{w_0^2\,(1 - m)^2}{2gm^2};\ l_1 = \frac{w_1^2\,(1 - m)^2}{2gm^2};\ .\ \ .\ \ .\ \ .\ \ l_m = \frac{w_n^2\,(1 - m)^2}{2gm^2};$$

which serve to find the real tidal heights of the sea level from the plane to which the observations have been referred, unaffected by the accidental errors occasioned by wave-motion, and corresponding to each interval of time ∂t. They are given by

$$(h_0 \pm l_0);\ (h_1 \pm l_1);\ (h_2 \pm l_2);\ \ .\ \ .\ \ .\ \ .\ \ .\ \ .\ \ (h_n \pm l_n);$$

in which the sign (+) will be used for decreasing heights, and the sign (—) will be used for increasing heights; or in other words, when the velocity w results positive, the correction l will be taken negative; and when the velocity w results negative, the correction l will be taken positive. [This results from the consideration that the internal level during the flow of the sea is lower, and during the ebb is higher than the external level.]

Now the whole question is to prove that the quantity

$$l_0 = \frac{32H^4}{g^3m^6T^6}$$

is really very small.

Calculating for a tide of $H = 4^{\text{m}}, 00$, and substituting $m = \frac{1}{2225}$, observing that $T = 22250$ seconds; will be found

$$l_0 = 0^{\text{m}}, 0000088;$$

The practicability of the proposed method seems fully assured by these figures, and we hope it will be taken in consideration by all whom it may concern.

STEEL FOR SHIP-BUILDING.

By John Haug, Marine Architect and Engineer.

The great progress made in the manufacture of steel, permitting its production in large quantities, of perfect uniformity and homogeneousness of structure at moderate prices, has caused a more general application of this material in cases where lightness, combined with strength, is an important object. Thus it has already been used for moving parts of machinery, steam boilers, bridges, for ship-building, etc.

For steamers of shallow draft, where the utmost lightness is the first question to be considered, its use has been almost compulsory, but its general application for ship-building did, for some time, not make very rapid progress. This has mainly been due to the over-zeal of its advocates, who, using steel of the high tensile strength of forty to forty-two tons per square inch, and reducing dimensions in proportion, soon found that its brittleness and want of ductility made it quite unfit for use, and altogether unreliable, besides requiring the utmost care in heating and working.

After a great number of experimental tests, and a still greater number of practical failures, a mild steel of from twenty-seven to thirty-one tons tensile strength per square inch, with an elongation of twenty per cent. on specimens of eight inches length, was found to be most suitable and entirely reliable, and requiring only ordinary care in its treatment.

The rules of "Lloyd's Register of British and Foreign Shipping" (as well as other classification societies) now recognize the above material as a substitute for iron, and permit a general reduction of twenty per cent. in thickness of plating, frames, etc., from those prescribed for iron ships.

To show the profit which the ship-owner may derive from the application of this material to a ship, the following example of a trans-Atlantic freight steamer, carrying 3500 tons (dead weight) is given.

If of iron, the hull will weigh about 2500 tons, and the entire ship will cost about $350,000; of steel, the hull will weigh 2000 tons, the total cost being $380,000.

Excess of cost, $30,000
Interest, 6 per cent.
Depreciation, etc., 6 per cent.

Total, 12 per cent. on $30,000 per year, $3600
Extra earnings.
500 tons cargo out.
500 " back.

1000 " on round trip.
Assuming 10 trips per year, will make 10,000 tons,
at $3.00 average freight per ton, $30,000

Makes extra net profit, $26,400 per year,
or 9·428 per cent. on entire cost of ship.

Thus it will be seen that a steel ship would pay a handsome profit where an iron ship would just pay expenses.

In other classes of ships the advantages of using steel will be found in different directions. In river steamers, tugs, etc., if greater carrying capacity were not required, the dimensions of the hull might be reduced to an extent corresponding to the reduction in weight, thus permitting a reduction in cost, in power and in consumption of fuel; or, with the same power, greater speed would be obtained; or, the same dimensions of hull would secure a lighter draft, etc., whichever would best meet the requirements of a particular case.

A few words might be said about the comparative durability of steel and iron. Earlier experience with steel of a high tensile strength had shown that this material corroded more rapidly than iron, but later experiments with mild steel, such as now used for ships, have given a contrary result.

Mr. Henry Bessemer (inventor of the well-known process) immersed a number of pieces of steel and iron plates in diluted acid, and found that the iron was acted upon in a very irregular manner, being deeply furrowed, while the steel always showed a smooth and uniform surface. Some later experiments made at the Terre-noir steel works, in France, showed that the comparative corrosion of different specimens of steel varied almost as their respective percentage of carbon. Steel containing more than $\frac{1}{3}$ per cent. of carbon corroded more rapidly, while that containing less showed a less amount of corrosion than wrought iron.

There can be no doubt that the use of steel for ships will increase also in the United States. Steel manufacturers in Pittsburg have already filled extensive orders for Western boat builders with success, and at such moderate rates that it can fairly compete with iron.

CELLULOID.

"It seems to me," remarked a gentleman the other day, "that about everything we have now, except what we eat, is made out of celluloid." An investigation of the subject almost tends to persuade one that this statement is scarcely exaggerated. Although celluloid was invented nine or ten years ago (by two brothers named Hyatt), its perfected manufacture has been regularly in progress for only about five years, and is considered to be still in its infancy; yet immense quantities of the substance are produced; it is converted into a wonderful variety of forms, and new modes of applying it are discovered almost daily.

Celluloid is a composition of fine tissue paper and camphor, treated with chemicals by a patented process. A rather common impression that it contains gun-cotton is a mistake, which arises from confounding it with collodion. Celluloid, it is said, is entirely non-explosive, and burns only when in direct contact with flame. When crude it looks like a transparent gum, and its color is a light yellow-brown. It can be made as hard as ivory, but is always elastic, and can be readily moulded into every conceivable form. With equal ease it can be colored in any tint desired, the dye running through the entire substance, and being, therefore, ineffaceable.

All the celluloid made is produced by a single company, with factories in Newark, N. J. This company makes only the raw material, which it sells to various manufacturing companies for so much per pound and a royalty on their net sales. No one can buy it unless the producing company decides to give him a license, which is granted only for the purpose of making some new article that will not interfere with the trade of the companies already licensed. A number of large corporations are now engaged in the various branches of manufacture for which celluloid can be employed.

The cost of the crude article to the buyers is regulated by the producing company according to the use to be made of it and the competition met with in other materials. For instance, $4 or $5 per pound are charged for celluloid which is to made into jewelry, while only $2 are charged if it is designed for umbrella handles, though there is no difference in the quality of the substance. In consequence of this system there is a similar wide variation in the cost of the manufactured articles.

As a close imitation of ivory, celluloid has made great inroads in the business of the ivory manufactures. Its makers assert that in durability it is much superior to ivory, as it sustains hard knocks without injury, and is not discolored by age or use. Great quantities of it are used for piano and organ keys, to the manufacture of which one company is devoted. So extensive is its use for this purpose that the ivory manufacturers have reduced their price for keys below that of celluloid, in the hope of checking the competition. "It is only a question of who can hold out longest," said a celluloid manufacturer; "but we can make our own elephants, and the ivory men have got to catch theirs."

Billiard balls are made of celluloid at half the price of ivory, and are said to be equally elastic, while more durable. Large amounts are used for combs of every variety, for the backs of brushes and hand-mirrors, and for all kinds of toilet articles which ivory is employed for. Even a fine-tooth comb made of celluloid is twenty-five per centum cheaper than ivory, while in large pieces, such as the backs of hand-glasses, the difference in price is enormous. Among many other articles in which celluloid takes the place of ivory or india-rubber, are whip, cane and umbrella handles, every kind of harness trimmings, foot-rules, chessmen and the handles of knives and forks. Its use in cutlery is said to be especially desirable, as it is not cracked or discolored by hot water.

India-rubber, as a general rule, holds its ground against celluloid, as the latter cannot be sold so cheaply. The celluloid is said to be much more durable, however, and it is superior for pencil-cases, jewelry, etc., where gold mountings are used, as it does not tarnish the metal, whereas the sulphur in india-rubber tarnishes gold which is less than eighteen carats fine. The freedom of celluloid from sulphur, and the natural flesh-color which can be imparted to it, have caused it to be extensively substituted for india-rubber in the manufacture of dental blanks, or the gums and other attachments of artificial teeth.

Celluloid can be mottled so as to imitate the finest tortoise-shell, and its elasticity renders it much less liable to breakage. In this form it is used, like the imitation ivory, for combs, card-cases, cigar-cases, match-boxes, pocketbooks, napkin-rings, jewelry and all sorts of fancy articles. The substance is employed for similar purposes as a good imitation of malachite and also of amber. It is made into mouthpieces for pipes, cigar-holders and musical instruments, and is used as the material of flutes, flageolets and drumsticks. For drumheads it is said to be superior to parchment, as it is not affected by moisture in the atmosphere.

As a substitute for porcelain, celluloid is used for the heads of dolls, which can be hammered against a hard floor without danger of fracture. Beautiful jewelry is made of it in imitation of the most elaborately-carved coral, reproducing all the shades of the genuine article. Most of the coral tints are bright or dark red, however, as the makers, strange to say, have found that excellent copies of the costly pink coral are not in popular demand.

One of the large manufacturing companies is employed exclusively in the making of optical goods, using celluloid in place of tortoise-shell, jet, etc., for the frames of spectacles, eye glasses and opera glasses. The material is extensively used for shoe tips, protecting the toe as well as metal tips, and having the appearance of patent leather. By shoemakers it is also used for insoles. Large quantities of thimbles are made of it, and it is said to be the best material known for emery-wheels and knife-sharpeners. As a ground for paintings, celluloid has all the advantages of ivory, and photographs can be taken on it which are alleged to be superior to ivorytypes.

Within the last year and a half another branch of celluloid manufacture has been developed which promises to reach enormous proportions. This is the use of celluloid as a substitute for linen or paper in the making of shirt-cuffs, collars, etc. It has the appearance of well-starched linen, is sufficiently light and flexible, does not wrinkle, is not affected by perspiration and can be worn for months without injury. It becomes soiled much less readily than linen, and when dirty is quickly cleaned by the application of a little soap and water with a sponge or rag. For travelers and for wear in hot weather this celluloid linen is especially convenient. It has lately been much improved by the introduction of real linen between two thicknesses of celluloid. Shirt-fronts have been made of it, as well as cuffs and collars, and it is believed that these will prove equally desirable.

Celluloid has been experimented with as a material for neckties, and although the trials have not yet been very satisfactory, it is thought that they will eventually be successful. For hat-bands and hat sweat-bands it is a trifle more expensive than the materials commonly used, but it is said to be better, as it does not become rusty or greasy. It has also been used lately for watch-cases.

There is a large export trade in celluloid articles to Cuba and South America, and this is constantly increasing. They are not sent to Europe, as the right to manufacture and sell them there has been sold to a foreign company, which has a factory in France.—*N. Y. Evening Post.*

THE "GARY MOTOR."

In a letter to the Secretary of the Franklin Institute, Professor Henry Morton, of the Stevens Institute of Technology, remarks concerning this application of magnetism for the production of motion as follows:

This so-called "Gary Motor" comes before the public in a double character.

First, as a perpetual motion machine, which is to do work without transformation of energy. In this light I think we may at once dismiss it as a fraud or blunder, to take its place with materialization of spirits, and other matters, which are not subjects for the investigation of scientific students.

Secondly, however, Mr. Gary appears as the supposed discoverer of some new facts in reference to the action of magnets, which, though they certainly can no more enable us to create energy than to create matter, may add to our means of utilizing natural forces and existing sources of energy.

In this view his claim of discovering what he calls a neutral line around magnets is worth investigation.

On looking into this matter, however, I find that he has only re-observed a set of phenomena which are so old as to have been described in the *Principia* of Sir Isaac Newton, Book II, Prop. xxiii, Scholium to Theorem, xviii, where I find as follows:

"The virtue of the magnet is contracted by the introduction of an iron plate, and is almost terminated by it; for bodies further off are not attracted by the magnet so much as by the iron plate."

All Mr. Gary's experiments, which will work, are readily explained by the well-known principles of magnetic induction, by reason of which a piece of soft iron near a magnet is inductively magnetized by the same and reacts upon it, and thus "contracts the virtue of the magnet" and neutralizes its action on exterior bodies.

There is no evidence whatever of the existence of any neutral lines about a magnet, but the very experiments cited by Mr. Gary as proving it simply demonstrate that in certain relative positions the opposing actions of a permanent magnet and a piece of soft iron magnetized by induction from it neutralize each others effects upon a third magnetic body, such as a piece of iron or a compass needle.

Fully to work out all the relations between the mutual actions of three such bodies in any case is of course a problem of considerable complexity, but by no means a new one, and among many others a very able discussion will be found in the *Philosophical Transactions* for 1831, by Sir Wm. Snow Harris, page 501 et seq., under the title "On the power of masses of iron to control the attractive force of a magnet." An earlier memoir by the same author appeared in the Edinburgh *Philosophical Transactions* for 1829.

Rain of Sap.—On the 22d of August, at 4 P. M., in a calm afternoon, with a temperature of 24° [65° Fahr.], and a clear sky, M. Ch. Musset was struck by the evolutions of some gnats under the spreading branches of two fir trees. Around some yews, under a linden, and about some other shrubs he observed similar swarms of insects, but less numerous; under other trees there were no gnats. He then perceived, falling in the form of a fine rain, an immense quantity of very limpid drops which became visible in the sun's rays. Similar observations were made during fifteen days, at all hours of the day and even in the night by lamplight. The sap is insipid, slightly purgative, colorless at first, but after standing some days it takes a light amber tint. He gives the following hypothetical explanation of the phenomenon. At the close of summer vegetation is checked, the tissues are hardened and consequently transpiration diminishes; but the sap continues to ascend, and, not being employed in assimilation, the excess is poured out by the stomata of the leaves.—*Comptes Rendus.* C.

Substitution of Artificial for Natural Dyes.—In closing his report upon the chemical products at the Paris Exposition of 1878, Gustav Engel anticipates the early displacement of natural coloring materials by artificial dyes. The discovery of artificial alizarine, indigotine and other similar products; the progress which industrial chemistry has made in the application of anilines, by procuring for some of them a permanence which was wanting for some time after their discovery, a permanence, in some cases, even greater than that of the natural products for which they have been substituted; the brilliancy of their tints; their ease of application and the important economy which is secured by their use, are all indications of the most promising character.—*Bull. de la Soc. Industr.* C.

Crystalline Resistance in Mother-Waters.—Guided by theoretical considerations Boisbaudran has made numerous experiments, which have appeared to show, among other things: 1. That the action of different isomorphic crystals is not the same upon the solution of one of them. 2. That the passage from the condition of very slow solution upon a crystalline surface to that of very slow increase cannot be made suddenly, by a slight change in the concentration of the liquid, but that every face remains intact, without either losing or gaining, in a mother-water of which the strength varies within several narrow but easily observable limits. 3. That the resistance to change is modified independently for each system of faces, so that an alteration in external conditions commonly produces a change in the relation of the resistances of two given systems of faces. 4. That, contrary to the opinion of some, there is no mobile equilibrium between a crystalline face and its mother-water, no continual exchange of molecules, but only a continual erosion or a continual deposit, or, between the limits of resistance, neither erosion nor deposit. Some months since M. P. Klocke published at Freiburg some conclusions contrary to these, but they appear to have been drawn without sufficient care. In order to conduct the necessary experiments properly they should be carried on in a place where the daily temperature varies only a few hundredths of a degree. Each of Boisbaudran's experiments required a long time, generally some months, and sometimes years. He worked in a deep cave, hollowed out of a thick rock, and enclosed by double doors.—*Comptes Rendus.* C.

Absorption of Water by Wood.—E. J. Maumené finds that the absorption power varies in different woods, when dried in a vacuum, between 9·37 per cent. and 174.86 per cent. The maximum, 174·86 per cent., or $\frac{7}{4}$ of its own weight, is found in chestnut timber. The moisture contained in wood, in its ordinary state, varies between 4·61 per cent. and 13·56 per cent. The absorption power varies but little in different samples of the same wood.—*Les Mondes.* C.

The Velocity of Light.—There are now in progress at the Naval Academy, preparations for a scientific investigation of an interesting character. Ensign A. A. Mitchelson, U. S. N., having delivered a lecture upon "Light" before an association of scientists, made in preparation for it a series of investigations that induced him to believe that he could determine more accurately than is now known the velocity with which light travels, the two accepted computations differing about a thousand miles in the distance asserted to be traveled in a second. Under orders from the Navy Department, Mitchelson has erected the apparatus to determine his theory practically.

The plan is essentially that used by Foucault, with the exception that a lens of great focal length, and a plane mirror, are used instead of a concave one. This arrangement permits the use of a considerable distance, and consequently gives a longer interval of time, which insures greater accuracy. The displacement of the image of a slit is the quantity to be measured, and this in Foucault's experiments was a fraction of a millimetre, and in the velocity of light could not be determined with any greater accuracy than could this displacement, which would be a fraction of one per cent. In the experiments made by Mitchelson the displacement has been increased to over one hundred millimetres; hence the error introduced by this measurement would be less than one-thousandth of the whole, or less than twenty miles.

Another, though not an essential feature, is the use of a tuning fork, bearing a mirror on one prong, and kept in motion by a current of electricity, by means of which the speed of the revolving mirror can be ascertained with the same degree of precision. The mirror is put in motion by a blast of air furnished by a small rotary blower, which is driven by a steam engine. By this means a very steady speed is maintained. The entire apparatus is nearly finished, and in a short time observations will be commenced at Annapolis.

Siliciuret of Iron.—The committee of chemical arts of the French *Société d'Encouragement pour L'Industrie Nationale* has undertaken the examination of the uses which can be made of this new compound. Prof. Lawrence Smith sent them an ingot weighing about three kilogrammes [6·6 lbs.], with a color like platina and a specific gravity of 6·5. It is easily broken by the hammer, does not rust in the air, is not corroded by concentrated nitric acid, and scarcely by any reagents except fluorhydric acid and melted alkalies at a red heat.—*Procés Verbaux de la Soc.* C.

The Effects of Salt Mining in Cheshire, England.—A deputation from Cheshire has recently made complaint of the injury done to property in the neighborhood of Northwich and Winsford, in consequence of the continual caving in of the earth from the subterranean extraction of brine for many years by the manufacturers of salt. The deputation declares that roads and bridges have fallen in; that the gas and water pipes are broken and destroyed in many places; that many of the houses are cracked and lean to one side, in consequence of the continual undermining of their foundations, and that as yet there has been no legal redress.

The salt beds of Cheshire are composed of massive deposits of mineral salt, buried in the ground 40 metres below the surface of the earth. Naturally, fresh water runs through the beds of sand and marl which cover the mineral salt, dissolves it and changes it into brine. The salt is obtained by means of impermeable pipes or wells that are sunk to the brine; then, by aid of pumps worked by steam, the brine is raised into reservoirs, where an artificial heat causes the liquid part to evaporate. The result of these operations is the salt of commerce, considerable quantities of which are exported to Asia, America, and all the countries of Europe. As there is pumped every year in Cheshire about one billion one hundred million gallons of brine, the damage which is caused to property holders is not astonishing. The superficial soil sinks little by little, the earth of the town becomes broken up, rain water accumulates, and the houses are threatened with ruin. The salt manufacturers urge, on the contrary, that they are doing good, as they employ large numbers of workmen, and attract to the district different industries. This curious state of things is about to occasion in England a lawsuit of great importance, the result of which it is difficult to foresee.—*La Nature.*

Researches on Hydrogen Peroxide.—E. Schoene.—The author has investigated the behavior of hydric peroxide with the oxygen compounds of thallium. He finds that thallium paper is turned brown by the vapor of hydric peroxide in consequence of the formation of thallic oxide. Hence the browning of thallium test-papers on exposure to atmospheric air is by no means a proof of the presence of ozone.—*Chem. News.*

Edison's Electric Light.—This has been advanced a step, and a very important one, as far as the inventor is concerned, by the granting of the patents for the lamp, and for the thermal regulator of the current. From the specifications, it is now positively known that the light is produced by the electric incandescence of platinum and iridium, the exact melting point of which has not been determined, but it is much higher than platinum alone. There have been many forms of these regulators, all based on one principle, namely, the degree of heat produced controlling the amount of the current passing through the metallic conductor, the light being occasioned by the resistance offered, while the regulator is intended to prevent it being heated so high as to melt it. In the case of carbon this is impossible, and consequently the light is much greater from that substance. In Edison's regulator the heat expands the air or fluid in the chamber containing the platinum, and a diaphragm is moved outwards, which in its turn controls the passage of the current by means of contact points of platinum. The diaphragm may give this motion to a lever or spring through which the contacts may be made. Mercury may also replace the air in the tube, and to prevent loss of heat by radiation, two concentric glass tubes may be employed with the intervening space filled with alum water or other poor conductor of heat, surrounding the light, which is very moderate compared with the electric arc. Great improvements have been made within a short time in dynamo-electric machines, notably by Houston-Thomson and other scientists, developing to a great degree their efficiency, and in some of the best forms as high as sixty per cent. of the energy, it is said, is converted into the electric current, leaving but little room for improvement, while but twenty per cent. is wasted in the heating of the machine, etc., which is nearly reversing the available power obtained from our best steam engines, where seventy per cent. passes up the chimney and is otherwise not used.

Chinese Cotton Spinning.—The Chinese Government has bought machinery in Germany, and has engaged experienced engineers and spinners, in order to establish cotton factories of their own, so as to become independent of importations from Russia and England.—*Fortsch. der Zeit.* C.

Influence of Duration and Intensity upon Luminous Perception.—Ch. Richet and Ant. Breguet have experimented with an apparatus which enabled them to produce flashes lasting only $\frac{1}{2000}$th of a second. They find that a feeble light which can be plainly seen when its influence is continued for some time, becomes invisible when its duration is reduced. To make it visible anew, it is sufficient either to increase its intensity or its duration. It can also be made visible by repeating the feeble and brief illumination at least fifty times per second. Colored lights obey the same laws and are always seen with their proper color, whether they are strong or weak, long or short.—*Comptes Rendus.* C.

The Draining of Lake Fucino.—One of the greatest engineering undertakings of the century, well fitted to rank with many attempted in Holland, not even excepting the projected draining of the Zuider Zee, is the successful accomplishment of this work by which the Appenine lake of our boyhood has become a thing of the past, and some 35,000 acres of the richest land recovered for cultivation. The labor of making the tunnel necessary for the task, and other works, has occupied nearly a quarter of a century, and Prince Torlonia has expended on the work more than ten millions of dollars. All the water has disappeared except a small basin used to drain the surrounding district. The greatest length of the lake was formerly some ten miles, and its breadth about seven, while the towns of Avezzano and Pescina are no longer in danger from the sudden rising of the water in this volcanic district. The idea of draining it is not a new one, and the remains of the aqueduct constructed under the reign of the Emperor Claudius were formerly shown to the traveler. This has been made use of in the present undertaking, and after the lapse of so many centuries the people of this Appenine district, some 2200 feet above the level of the sea, are rejoicing over the completed work. Upon visiting the spot a few years hence, how difficult it will be to realize that these vine-clad hills were covered with water within so brief a period.

Compressibility of Gases at High Pressures.—E. H. Amagat has experimented in a shaft with a depth of 380 metres [415·57 yds.] upon the compression of gases by a mercurial column. He reports three sets of experiments upon nitrogen: the first was extended to 208, the second to 330 and the third to 430 atmospheres. The results of these three series are remarkably uniform and the curve which represents them is perfectly regular. Under the pressure of 430 atmospheres the volume of the gas is nearly a quarter greater than is indicated by Marriotte's law, which corresponds to a difference of nearly a hundred atmospheres.—*Comptes Rendus.* C.

New Spectral Rays in Samarskite.—De Boisbaudran has been examining, by the spectroscope, some samarskite, which is rich in didymium. He observed rays or bands which do not correspond to any body hitherto known, nor to the descriptions of the spectra which hav been recently announced by Messrs. De la Fontaine, Lawrence Smith, Soret and De Marignac. The new rays, both of emission and of absorption, appear to represent a single body. The metal which occasions them is precipitated as a double potassic sulphate along with the didymium; its simple sulphate is a little less soluble than that of didymium; its oxalate is precipitated before that of didymium; finally, ammonia separates at first the oxide of the new body and afterwards the oxide of didymium.—*Comptes Rendus.* C.

Imitation Ivory.—Harris' patented imitation ivory is made by dissolving 100 grammes of glue in 1 litre of water, 50 grammes of of alum in one litre of water, and mixing 50 grammes of good bleached cellulose with 3·5 litres of water. The moulds are carefully oiled with a mixture of equal parts of goose grease and lard; then a mixture is formed, in an earthen vessel, of 75 grammes of the glue solution, 200 grammes of the cellulose water, 200 grammes of water, 250 grammes of finely sifted gypsum and 200 grammes of the alum solution. This mass is placed in moulds by a spoon, shaken so as to remove bubbles, and left to set and thicken. It is then removed from the moulds, covered with a woolen cloth, the superfluous water pressed out, and, after it has completely stiffened, the fat is removed by hot water. It is then dried and soaked in a hot mixture of equal parts of wax and stearine. After cooling it is brushed until the ivory lustre shows itself.—*Dingler's Journal.* C.

Increase of Meat Exports.—In 1876 the whole quantity of American meat exported to Great Britain was 16,165,632 lbs. In 1878 the export had increased to 53,661,216 lbs.—*Fortsch. der Zeit.* C.

Locusts in Algiers.—Captain Brocard states that the recent invasion of locusts in Algeria demonstrates some new advantages in meteorological and climatological studies. It has long been noticed that the sirocco and drought favor, in a high degree, the development of these pests. whilst cold and stormy weather prove fatal to them. He proposes to devote himself to a careful study of the observations which he has collected with great difficulty, in the hope that they will lead to the discovery of some simple law for determining upon the measures which will be most efficacious for the destruction or the utilization of the locusts.—*Les Mondes.* C.

An Electric Blowpipe.—M. Jamin.—The author remarks that the electric arc which plays between two carbon conductors is a true current. If submitted to the influence of a neighboring current, of a solenoid, or of a magnet, it experiences an action regulated by the laws of Ampère, identical with that experienced by any metallic conductor put in its place, but as its mass is exceedingly trifling its speed is considerable. The author takes advantage of this fact to submit small quantities of matter to an intense heat. By causing the arc to be driven upon lime, magnesia or zirconia, the light is directed downwards and its intensity is increased at least three-fold.—*Comptes Rendus.*

Detection of Salicylic Acid in Beer.—By M. Blas.—It is found that a quantity of salicylic acid, less than ·075—0·1 gramme per litre, when added to beer, cannot be detected with certainty if the ferric chloride reaction be employed, either with the original beer or after precipitation by lead, or after treatment by animal charcoal. It is much more simple to test for the presence of the acid in the urine voided after drinking the beer, when 0·0012 per cent. can with ease be detected. If 20 c. c. of the urine be examined three hours after the beer has been drunk, it will be found that ferric chloride at first produces a precipitation of phosphates, but after their separation the violet reaction is distinct. For the preservation of light beers 0·5 gramme of salicylic acid is sufficient, but 0·2 gramme per litre must be added to strong beers; more than this quantity is unadvisable, as a taste is imparted to the beer; the addition of salicylic acid to beer cannot destroy any of the integral constituents, acting only as a preservative.—*Jour. Chem. Soc.*

French Sleet.—In a recent storm, the ground and trees in many parts of France were covered with a crust of ice of remarkable thickness for that country. Some of the leaves were loaded with a weight of ice fifty times as great as their own weight. Trees, telegraphic wires and nearly all external objects had a crust of two centimetres ($\frac{4}{5}$ inch). Many branches were broken when the thaw commenced. E. Masse thinks that the drops of water were in a state of superfusion at a temperature below zero, and that the crystallization was started by the simple mechanical contact of the drops with solid bodies.—*Comptes Rendus*. C.

Coffee Parasites.—It seems as though each of the plants which are employed for the food of man must in its turn suffer from the attacks of a destructive animalcule. While the phylloxera is continuing its ravages in the French vineyards, a similar scourge threatens to destroy the coffee plantations of Brazil. In the province of Rio Janeiro the leaves often grow suddenly yellow, and in a short time the tree dies; the trouble seems the more inexplicable because the most vigorous plants, those from seven to ten years old, were the first to succumb. Dr. Jobert found, by close observation, that the roots of the dead plants were covered with excrescences similar to those produced by the phylloxera; the interior of these warts was composed of cells containing worms which measured scarcely a quarter of a millimetre [·01 in.]. Dr. J. estimated that upon a single tree there were not less than thirty millions of these parasites.—*Les Mondes*. C.

New French Observatory.—M. Mascart, the director of the French central meteorological Bureau, presented to a late session of the scientific association the plan for establishing an observatory on the summit of Mont Ventoux, N. E. of Carpentras. It rises suddenly 1960 metres [1·22 miles] above a great plain which extends without any marked interruption to the shores of the Mediterranean; it is easy of access at all seasons and is isolated from any interfering influence by neighboring summits. An observatory at this point would complete for the south of France the system constituted upon the north by the observatory of the Puy-de-Dome, and on the southwest by the observatory of the Pic-du-midi; it would furnish valuable indications for meteorological forecasts, useful both to sailors and to agriculturists, and it will be able to render important service to science in various other ways. The cost of the buildings and road will not exceed 150,000 fr. [$30,000].—*Bull. de la Soc. Scientifique*. C.

Adhesion of Mortar.—In building the Pont de Claix, some experimental blocks were joined by mortar which was allowed to harden for three years, when the mortar was broken by an average load of 10·0125 kilogrammes per square centimetre [142·228 lbs. per square inch]. This experiment seems to show that the adhesion of mortar to stone is only about one-third as great as the cohesion of the mortar itself. The result is noteworthy, as this adhesion is the true measure of the resistance of masonry. Further experiments of a similar kind are desirable, in order to establish formal conclusions.—*Ann. des Ponts et Chauss.* C.

Comparison of Obelisks.—In erecting the obelisk of Luxor more than 200 men and a very complicated mass of machinery were required. Only 25 men and very simple apparatus were used in erecting Cleopatra's Needle upon the Thames embankment. The transport and erection of the obelisk of Luxor cost the French Government nearly 1,500,000 francs; the expenses for the same operations upon Cleopatra's Needle only reached about one-fourth of that amount. The following figures give a comparison between the two obelisks:

	Cleopatra's Needle.	Obelisk of Luxor.
Height,	68·5 ft.	74·9 ft.
Volume,	2528·98 c. ft.	2945·62 c. ft.
Weight,	186 tons.	225·9 tons.

—*Ann. des Ponts et Chauss.* C.

Elasticity of Alloys.—M. Phillips reports some experiments for the determination of the coëfficient of elasticity and of the limiting elasticity of different bodies. He refers especially to a new alloy which was melted and cast by Matthey of London. Its density at the freezing point is 21·6139. Its composition is:

Platinum,	80·660
Iridium,	19·079
Rhodium,	·122
Iron,	·098
Ruthenium,	·046
	100·005

This alloy is so malleable and ductile that M. Sainte-Claire Deville possesses a thread of it which is only a few hundreths of a millimetre in diameter and is scarcely visible. A hundreth of a millimetre is only $\frac{1}{2500}$ of an inch.—*Comptes Rendus.* C.

A New Academy.—On the 13th of January the Humboldt Academy was opened in Berlin. The object of the institution is to furnish an opportunity to supply special deficiencies of education to persons who have not been able to avail themselves of a regular course of university instruction.—*Fortsch. der Zeit.* C.

Lime Cartridges.—Unslaked lime may be substituted for powder in quarries if it is compressed into cartridges, placed in the drill holes and then saturated with water. By using these cartridges in coal mines there is less waste from small coal than when ordinary powder is employed, and there is less danger of accidents from the flying fragments and from vitiated air.—*Fortsch. der Zeit.* C.

Soundings in Algeria.—Commandant Roudaire reports that two soundings have been completed and a third is under way. After penetrating to ten metres [32·8 ft.] below low water level he found nothing but sands and marly clays. The Arabs come in flocks in search of work. It would be easy to obtain any number at 90 centimes [18 cts.] per day. Fresh water is found at the depth of four metres [13·12 ft.] below the surface of the isthmus of Gabés, even at points which are most elevated above the level of the sea. The advantage of this supply will be readily seen upon reflecting that in the piercing of the isthmus of Suez it was necessary first to employ 2000 camels to bring water to the workmen, and afterwards to bring the water of the Nile along the docks by means of a canal.—*Comptes Rendus.* C.

Wood Dyeing.—G. A. Schoen wished to give an old appearance to some articles of oak wood by rubbing them with oil of aniline, which, as is well known, browns rapidly, but he could only produce a mahogany tint. He then first painted the wood with a solution of aniline salt which penetrates the wood very rapidly, and colors it yellow. He next gave a coating of a solution of caustic soda, to set the aniline at liberty, when there immediately appeared a deep brown hue like that of old oak. The same effect was observed in walnut, plum and other wood. He was equally successful in giving a black tint to various kinds of wood by impregnating them successively with aniline salt, bichromate of potash and soda, allowing them to dry after each application. The coloring was very uniform, penetrating the knots as well as the softer portions of the wood.—*Bull. de la Soc. Industr.* C.

Tin in Tasmania.—Tasmania appears to be rapidly becoming a second Cornwall. Four years ago the tin and tin ore exported from the colony amounted to only £7000, but in 1877 it reached nearly £270,000. The tin ore contains some gold, which increases its value.—*Fortsch. der Zeit.* C.

The First Steel Bridge in America.—Arrangements have been concluded by General D. D. Smith, Chief Engineer of the Chicago and Alton Railway, for constructing the first all-steel bridge in America. General Smith will be remembered by his connection with the U. S. Government Board for Testing the Strength of Iron and Steel, experiments which were carried on by him several years ago. His researches have at last brought him to the conclusion that steel bridges can be built cheaper than iron, and be equal in durability. The bridge will be erected over the Missouri River on the Chicago and Alton Railway. It will be of five spans of 350 feet each. The elevation over high-water mark will not be less than 80 feet, at which height the light steel rods of the "Howe truss" will look like silver cobwebs, glimmering in the sunshine. For all its frail appearance, the bridge will have a strength reached by but few existing structures in the world. The total amount of steel used in the construction will be about 1500 tons, equivalent to almost double that quantity of iron.—*Am. Journal of Industry.*

The Electric Light in Salt Mines.—An experiment has recently been made in the application of the electric light in the Marston Salt Mines, near Northwich, England,one of the largest in the world.

The space to be lighted is seven or eight acres, and 30 feet in height, and a single electric lamp was found sufficient to illuminate the whole, by the reflection from the surfaces of the walls of salt. The distance from the machine to the lamp in the experiment was 300 yards. The The conducting wire was carried down the shaft, which has a depth of 120 yards, then to the lamp, and the metal guides to the cogs were utiilized in the entire circuit. The lamp had an illuminating power of 6000 candles, and the effect from the newly quarried portion of the crystal rock was magical, the reflected light assuming a variety of colors.

Beside the other advantages of the electric light the cost in comparison with candles, heretofore used, promises well for its adoption.—*Iron.*

Hydro-Electricity and Hydro-Magnetism.—M. C. A. Bjerknes reports to the French Academy the results of experiments for verifying his theories. The experiments were performed in the physical cabinet of the University of Christiana with the aid of M. Svendsen, and resulted in the complete verification of his theories. They embraced, first, the action between two pulsating bodies; second, between a pulsating and an oscillating body; third, between two oscillating spheres. In every instance, even when it was necessary to place the vibrating bodies where it was suspected that the disturbing action of secondary forces would become very strong, the results conformed to those of the analytical researches, whenever the vibrations were regular and had a nearly uniform intensity. The attractions, the repulsions, the normal displacements from the central line, and even the deviations around the centres of the oscillations were such as his formulas had announced.—*Comptes Rendus.* C.

Book Notices.

SLIDE VALVE GEARS. By Hugo Bilgram. Philadelphia: Claxton, Remsen & Haffelfinger. 1878. 12mo, pp. 125.

Steam engine designers fully appreciate the advantages of diagrams for showing the functions of the valve gear graphically, and Zeuner has generally been considered the best, the only difficulty being that, when applied to link motions and other complicated cut-off gears, mathematical and geometrical intricacies have to be unraveled, which is a somewhat tedious process to practical men.

By a modification of Zeuner's diagram, the author of the above work has rendered this process entirely graphical, at the same time securing greater distinctness and clearness with regard to the positions and measurements required.

The introduction gives a clear and concise explanation of the distribution of steam in the cylinder, while Part I treats of the common slide valve, Part II of link motions, and Part III of independent cut-off gears, and the author, even in treating the most complicated problems, fully establishes the simplicity, distinctness and clearness of his diagrams.

Among those matters that are treated in an original yet simple manner may be specially mentioned: area of ports, velocity of valve, scope of the common valve, influence of obliquity of rods, theory of link motions, their irregularities and the correction of the latter, the influence of the mode of suspension, the investigations of different independent cut-off gears, etc. The author's patent cut-off gear, while simple in its construction, is a somewhat difficult problem to study, but may be considered one of the most interesting.

While there are many works on valve gears intensely practical, others again intensely scientific, the present treatise may be called "practical on a true scientific basis," and for this reason it will be especially valuable to students. J. H.

THE RELATIVE PROPORTIONS OF THE STEAM ENGINE. By W. D. Marks. Philadelphia: J. B. Lippincott & Co. 1877. Small 8vo, pp. 161.

Legion is the number of *Hand* and *Pocket* books that treat of the above subject, but the rules given by the majority of them are of the most rude and empirical kind; generally all the proportions are deduced from the diameter of the steam cylinder; sometimes the stroke and pressure of steam may be taken into consideration.

Now this might be well enough for a workshop, where only one style or class of engine is built, but it will inevitably lead to failure at the least departure from the beaten track.

The above work is written with a view of effecting a radical cure of this evil, by going back to first principles, in investigating the actual strain upon each part of the steam engine, and proportioning it in accordance with the laws of the strength of materials. This treatment also gives students a thorough understanding of the principles of constructing details, freeing them from the necessity of mere copying and following precedents.

The author frequently cites and refers to eminent writers like Weisbach, Reuleaux, Rankine, etc., sometimes simplifying and condensing their too intricate arguments.

The articles on piston and connecting rods (both iron and steel), showing how far in practice some theoretical considerations may be neglected; those on crank pins, journals and boxes, also investigating the influence and work of friction; on the action of the reciprocating parts; on different forms of cranks; on flywheels, etc., are interesting, and show considerable original research. J. H.

THE STRENGTH OF MATERIALS. By William Kent, M. E. New York: D. Van Nostrand. 1879. 16mo, pp. 139.

This little book is written with various objects in view, the first and most important being to show the wrong basis on which the tests (as a general thing) are made, having for results figures which are not compatible. This is owing, as the author justly explains, to the want of harmony in the experiments; for example, it would be absurd to compare the strength of two metals of the same nature that had been submitted to a pressure of several thousand pounds when the samples chosen were not of the same length or section, etc. We are sorry to say that such is the case, and our engineers rely too much upon experiments of others rather than their own, having for results accidents too numerous to mention. If these tests were complicated or required considerable time, there might be a pardonable excuse, but as a general thing they are most simple, and can be accomplished in a few hours, or even minutes, as the case may be.

The author gives a synopsis of the various methods of testing the strength of materials, and shows the probable error one has to contend with, and the manner of preventing the same. We are glad to see that the graphical comparative diagrams have been recommended, as these give the experimenter a much better idea of what he is to expect than the tables that too frequently help to fill a volume. In conclusion, the reviewer would state that the interesting articles by Professor Thurston and Mr. Townsend which have appeared in this journal are frequently and judiciously referred to. W.

FORMULÆ FOR THE CALCULATION OF RAILROAD EXCAVATION AND EMBANKMENT. By John Woodbridge Davis, C. E. New York: Gillis Bros. 1877. 8vo, pp. 106.

This method consists in finding first an approximate volume by averaging end areas, and if greater accuracy be desired, it may readily be obtained by applying a formula for corrections which gives the difference between the approximate and true contents for ground of any figure. The results are systematically arranged, and the labor of calculating continuous excavations over very irregular ground is greatly abridged. The work is used as a text-book in a number of our engineering schools, and the method is destined to become general. We can cheerfully recommend it. H.

LES PONTS DE L'AMERIQUE DU NORD ETUDE, CALCUL, DESCRIPTION DE CES PONTS. Par L. Ant. Comolli, Ingénieur. Paris: Lefevre. 1879. 2 vols. Text and plates.

This work is a treatise on the various systems of iron, wooden and combination bridges erected, or in process of construction in America. The text (a quarto) contains 213 diagrams and figures illustrating the various systems, and gives a brief analysis with strain diagrams. The folio atlas contains 54 plates of bridges, *in situ*, with details and dimensions.

The theoretical discussions are based upon the method of moments, and for the strength of materials the formulæ of Hodgkinson and Gordon are employed. The analyses are simple and clear, and the work generally quite complete. We fail, however, to find more than a single instance of the tubular girder, and the greatest type of that class, viz., the Victoria bridge, is not mentioned.

The same may be said of the magnificent structure crossing the Mississippi River at St. Louis, of which only a brief notice is given in the text, extending over a few lines. The plates and paper are not of a very good quality, but sufficient to illustrate the work, and all that should be expected for the very reasonable price at which it is offered—45 francs. H.

RAILWAY SERVICE. Trains and Stations—describing the Manner of Operating Trains and the Duties of Train and Station Officials. By Marshall M. Kirkman. Published by the Railroad Gazette, New York. 8vo, pp. 271.

This is a practical little work on the important subject above indicated. The duties of operating roads are sometimes entrusted to inexperienced or careless men, who risk the lives of their patrons by neglecting ordinary precautions. With such a guide as this manual before them, and the exercise of proper care, any manager should be able readily to eliminate from travel all accidents except those resulting from breakage or fire.

The author has carefully compared the numerous systems in use in both England and America, and gives his results in a clear and condensed form, with numerous rules for making up and dispatching trains, methods of signaling, rights of trains, instructions to employees, and all kindred subjects, constituting a manual which should be in the possession of *every* railroad employee or agent. H.

TURBINE WHEELS. By Prof. W. P. Trowbridge. New York: D. Van Nostrand, 1879. 16mo, pp. 88.

TREATISE RELATIVE TO TESTING OF WATER WHEELS, ETC. By James Emerson. Willimansett, Mass.: Published by the Author. 1878. 16mo, pp. 216.

These two works are grouped in one notice as presenting the two extremes of information desirable to possess in turbine construction.

The first treatise is one of a series of reprints from *Van Nostrand's Magazine*, which have been published separately under the name of "Science Series," intended to convey information in physics and mechanics from the best authorities with the latest acquired knowledge. In this instance the treatise on "Turbine Wheels" is a simple discussion of the condition of impact and reaction of the stream of fluid in contact with, or deriving direction from contact with, the guide, or blade. This inquiry is divested generally of all mechanical construction, except the exhibition of six methods of combining the pipe for carrying the influent water, the wheel to which motion is imparted by the flow of water and the pipe dispersing the effluent stream; and adopting these methods the study is restricted to some consideration as to the flow of water in contact with blades of accepted shape.

The merit of the turbine as a motor consists in the propositions first demonstrated by Fourneyron, that it was possible to attain with defined relation of dimensions of a wheel having blades of certain shape; through or between which a stream of water was permitted to flow freely, that is, without any obstruction in the nature of a closure, a useful effect nearly equivalent to the complete motive power derivable from a given flow of water, considered as weight falling so far each instant of time. The wheels themselves in crude form mechanically, but typical to most if not all of the recent so-called improvements, had existed for years if not centuries in the mountainous parts of France and Germany, and Fourneyron is believed to have first considered and developed their capability. Although he adapted to practice one form, he was not at all an inventor of that form. He elucidated the possibilities of a whole class of water motors at the time when the science of millwork allowed the economic substitution of metallic construction for the old wood work of the millwright. The turbine of to-day, as a whole, not a particular form, is Fourneyron's. Not that some one else would not have initiated the consideration, had Fourneyron not done so, but that he and he alone did initiate it in its totality.

The study commenced by Fourneyron was pursued by others, of whom notably Weisbach, the most thorough investigator in practical mechanics in this century perhaps, added most to the theory of the turbine. It is not to be denied that the best authorities in theory make mistakes. The computations of daily life are full of blunders. Weisbach is freer from error than most other authorities and he is more complete in his theory. There are certain things which become accepted in text books. Thus the proposition, which is the foundation of the Poncelet wheel, that maximum effect is obtained when the water enters the wheel without shock and leaves it without velocity has had general acceptation as a theory, while the impossibility of the conditions have been admitted, and Weisbach with others have pursued their investigations on more tenable bases. The assertion may remain, the application is completely ignored.

The student in science or in the limited branch of practical mechanics who *accepts* authority most inevitably go wrong; he has two causes of error, first that in his text book, and second that of his reading of his text book. "Prove everything and hold fast to that which is good." It remains to say that this little treatise of Prof. Trowbridge is a valuable addition to the study of the turbine.

The second work by Mr. Emerson is a singular collection of experimental and other data on sundry and several patented turbines. Unless some singular peculiarity call for a new study, the mill-owner of to-day must seek some turbine which has a commercial existence; one of which the details of construction shall give a durability in service as well as a high theoretic economy. From this book as authority the would-be purchaser can take a choice. It is a book calculated to instruct him especially as to who will accurately test his turbine after he has purchased it. It may not be so happy for the purchaser to appreciate that he has to deal with men who, as turbine builders, are asserted by Mr. Emerson to be incapable of doing "*a strictly honorable turbine business under existing circumstances*" (the italics are in the original). People will buy fast horses, and they will get cheated. "Purchasers require the highest results at the lowest prices, and there are scores ready to guarantee such, so far as talk is concerned."

As a collection of data of patented turbines having had commercial standing the past ten years, this book of Mr. Emerson is a desirable possession to the hydraulic engineer, and will yearly become of greater value when the publication shall exhibit what one is free to adopt in the details of construction of the correctly proportioned turbine. B.

VOUSSOIR ARCHES APPLIED TO STONE BRIDGES, TUNNELS, DOMES AND GROINED ARCHES. By William Cain, C. E. New York: D. Van Nostrand, 1879. 16mo, pp. 196.

This little treatise forms No. 42 of Van Nostrand's Science Series, and is a continuation of No. 12 of the same series. The author has endeavored to introduce to American readers the fundamental principles of Dr. Scheffler's theory of arches. We do not understand why at this day an effort should be made to revive a theory which, though unquestionably the best at the time of its publication (1857), has since been greatly improved and almost entirely superceded by the method of graphical statics. But, as the treatment is simple and limited to practical cases, and as the results are nearly the same as those given by later theories, it may be useful especially to those who are unaccustomed to graphical solutions. In the first number the author considered incompressible voussoirs, in the present the effect of the compressibility of the material is examined. The ultimate conclusions, however, are found to be the same as before, but the applications have been greatly extended. After giving some general principles, one of which, asserting the entire absence of tensile strains in a voussoir arch, we think should be seriously doubted; the author investigates the stability of arches in general, adding some practical suggestions. Then he shows the influence of spandrel fillings and gives the proper dimensions for keys and widths of abutments and piers. Following are some theoretical discussions on the height of surcharge necessary to bring the line of pressure to the centre of the arch ring, and on the lines of pressure corresponding to minimum and maximum horizontal thrust. The latter half of the volume is taken up with a very complete treatment of underground arches (culverts and tunnels), groined and cloistered arches and domes. The author generally recommends even narrower limits for the line of pressure in these various structures than the usual "middle third," and also that the depth of arch stones should always be increased towards the abutment. He occasionally finds it convenient to resort to graphical constructions on account of their simplicity and elegance, but does not consider them in the light of special cases of a general method covering the entire subject. The little book is well filled with practical examples illustrating the various propositions. It is to be regretted that the subdivisions were not more clearly stated and arranged, also that neither a table of contents or an index has been inserted. It requires a careful search among 196 pages to find a desired problem, and for practical use this is certainly a great inconvenience. H.

THE PATTERN MAKER'S ASSISTANT. By Joshua Rose, M. E. New York: D. Van Nostrand, 1878. 12mo, pp. 324.

The title of this work is not conformable to its preface, which sets forth that it is intended "to be useful to apprentice pattern makers and also to practical machinists." An examination of the book is not satisfactory to establish that it will fill either requisite. In no one regard is it thorough. The calling of a pattern maker cannot be set forth with the fulness which the apprentice or machinist requires in the small book now offered, while the tables and data which a competent pattern maker requires for reference are much more extensive than are here given. The common handbooks for the mechanic will be found to contain more full general tables, while the particular ones given are far from convenient for a pattern maker's use. With much novel information in the practice of the pattern room and foundry, there is so much not said, that the work is not a safe instructor to the novice and of little use to the skilled mechanic. B.

Franklin Institute.

HALL OF THE INSTITUTE, April 16th, 1879.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 154 member and 29 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers and reported that at the last meeting 8 persons were elected members of the Institute, and reported also the following donations to the Library:

Bulletin of the Royal Academy of Belgium. Vol. 1, 1832, to Vol. 46, 1878, inclusive.

Indexes to First Series, 1832—1856, and Second Series, 1857—1866.

Annuaire of the Academy, 1846 to 1858, and 1860 to 1879, inclusive. From the Academy.

British Patent Specifications and Drawings. From Nos. 4501 to 4949, 1877, and from No. 1 to 1200, 1878.

Disclaimers and Memorandums of Alterations. No. 1408, 1870; 3101, 1873; 3217, 1876; 244, 2294, 3011, 3213, 1878.

Abridgments of British Patent Specifications relating to
1st. Agriculture. Div. 1. Field Implements. 1867—1876.
2d. Bleaching, Dyeing, etc. Part 3. 1867—1876.
3d. Letterpress and Similar Printing. Part 2. 1858—1866.
4th. Photography. Part 3. 1867—1876.
5th. Washing and Wringing Machines. Part 2. 1867—1876.
London, 1878.

Report on the Meteorology of India in 1876. By H. F. Blanford. Second year. Calcutta, 1878.

Report on the Administration of the Meteorological Department of the Government of India in 1876–77.

Indian Meteorological Memoirs. By H. F. Blanford. Vol. 1. Part 2. Calcutta, 1878.

From the Meteorological Department of the Government of India.

Quarterly Weather Report of the Meteorological Office. Part 4. October—December, 1875. London, 1879.

From the Meteorological Committee of the Royal Society.

Reports and Charter and By-Laws of the Fairmount Park Art Association. 1871 to 1879. From J. B. Cox, Secretary.

Atmospheric Electricity. By David Brooks. Philadelphia.
From the Author.

Sixth Annual Report of the Lowell Water Board to the City Council. January 13, 1879. From A. A. Haggett, President of the Board.

Quarterly Report of the Chief of the Bureau of Statistics. Treasury Department. For three months ended Sept. 30, 1878.
From Chief of Bureau of Statistics.

Jura Trias Section of Southeastern Idaho and Western Wyoming. By A. C. Peale, U. S. Geol. and Geog. Survey. From the Author.

Verein der Deutschen Ingenieure. Verzeichniss der Mitglieder. 1879. Berlin. From the Society.

Transactions of the American Institute of Mining Engineers. Vol. 6. May, 1877, to February, 1878. Easton, 1879.
From the Institute.

Geological Survey of Japan. Report on the Second Year's Progress of the Survey of the Oil Lands of Japan. By Benj. Smith Lyman. Tokei, 1878.

From K. S. Otori, Chief Secretary of Public Works of Japan.

Ninth Annual Report of the Board of Directors of City Trusts. 1878. From the Directors.

Annual Report of the Operations of the United States Life-Saving Service for the Fiscal Year ending June 30, 1878.
From the Treasury Department.

Report of the Philadelphia Yellow Fever Committee. Appointed Aug. 22, 1878.
From the Committee.

Annual Report of the Friends' Free Library and Reading Room, with Catalogue of New Books.
From the Library.

Annual Report of the Director of Harvard College. Presented Nov. 14, 1878. Cambridge, 1879.
From Prof. E. C. Pickering.

Transactions of the Literary and Historical Society of Quebec. Session of 1878. Quebec, 1879.
From the Society.

Annual Report of the State Geologist of New Jersey. 1878.
From the State Geologist, G. H. Cook.

Publications of the Royal Institute of Superior Study, Florence, Italy, as follows:

- Session of Philosophy and Philology. Vol. 1 and Vol. 2. Parts 1—5, 1875—1877.
- Il Commento Medio di Averroe alla retorica di Aristotele. Fascigàlo 1. 1877.
- Session of Physical and Natural Sciences. D. G. Gavanna. Studi E. Ricerche sui Pichogonide. Part 1. Anatomy and Biology. 1877.
- Session of Physical and Natural Sciences. Vol. 1. 1877.
- Session of Medicine and Surgery. Vol. 1. 1876.
- Opere publicate dai professori della sezione di scienze fisiche e Naturali del R. Instituto superiore.

Annual Report of the Adjutant-General of Pennsylvania for 1878.
From J. W. Latta, Adjutant-General.

Astronomical and Meteorological Observations made during the Year 1875 at the U. S. Naval Observatory. Rear-Admiral C. H. Davis, Superintendent. Washington, 1878.
From Naval Observatory.

Specifications and Drawings of Patents, U. S. Patent Office, for October and November, 1878.
From U. S. Patent Office.

Mr. George Richards read a paper on "Machines and Implements for Measuring." An interesting discussion followed the reading of the paper, participated in by Messrs. Shaw and Jenks.

Mr. Goodwin described his Gas Stoves, and pointed out their merits, and their economy over the ordinary cooking range. A variety of sizes of stoves were exhibited.

The Secretary read a paper on the History and Construction of Type-Writing Machines, in which it was claimed that the instrument as now made is as nearly perfect as it is likely to be. The agent, Mr. Travis, exhibited his skill in writing with it. Manifold copies, and other specimens were distributed to the members. One of the early machines was also shown and the great difference in construction pointed out.

Massey's Arcagraph for describing Segments of Circles was next exhibited, and a brief account of it read. The instrument is a practical one. By its use the segment is described directly upon the board or other material to be used, and as many segments as may be required to form the arch laid out with precision.

Sidle's Centering Turn-table, for mounting microscopic objects, was shown, and its arrangement for centering the slide, which is done by means of toothed wheels beneath the table, explained. The feet can be detached from the stand, and the clamping screw used to secure it firmly to the table if desired.

Warner's Water-tube Boiler was described, and a model shown. A mysterious clock in which the works are concealed in the base, and the movement transmitted to the hands by means of a glass rod which passes through a glass tube supporting the skeleton dial, was exhibited, as well as MacQueen's Pipe Clearer conveying the force of the hydrant directly to the obstructed pipe.

The construction of the Retort Gas Stoves of the Providence Company, Rhode Island, was explained, and the greatly increased heat, from the superheating of the gas, mentioned. Several styles of the stoves and ovens were shown. A magnificent photograph of the Arch of Constantine, 30 inches by 40 in size, taken and printed from one negative, was exhibited.

The President announced the death of Dr. Isaac Hays, who was the ninth on the list of signers to the Constitution of the Institute. Dr. Hays was elected Corresponding Secretary of the Institute in January, 1828, which office he held until January 1840, when he was succeeded by Prof. Alexander Dallas Bache.

Mr. Mitchell moved that a committee be appointed by the President to prepare suitable resolutions on the death of Dr. Hays, which was adopted. Mr. Frederick Fraley, Dr. Robert E. Rogers and Mr. Charles Bullock were named as the committee.

On motion, the meeting adjourned.

ISAAC NORRIS, M.D., *Secretary pro tem.*

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PEAUCELLIER'S COMPOUND COMPASS AND OTHER LINKAGES.

By WM. D. MARKS,

Whitney Professor of Dynamical Engineering, University of Pennsylvania.

The writer, in order to avoid the use of cumbersome beam compasses, having designed for the use of his students a compound compass, upon the principles first enunciated by Peaucellier, and not being aware of the existence of specific directions for the construction of a similar apparatus, believes that the following directions may be of use to the engineering profession, as being sufficiently explicit to admit of the construction of curve rulers by those able to follow the simplest mathematical work.

The theory cannot be set forth in a more interesting manner than in the subjoined translation of a paper written by the inventor, and published in the *Nouvelles Annales de Mathématiques*, Deuxieme Série, t. xii, p. 71. 1873.

NOTE UPON A QUESTION OF COMPASS GEOMETRY.

By M. PEAUCELLIER.

(This problem, dated 1864, was solved at that time, as indicated by a letter in the *Nouvelles Annales de Mathématiques*, 2e série, t. iii, p. 414.)

We shall give the name of Compound Compass to any articulated system whatever of rigid pieces in complete connection (*a liaison complète*). We know that this name is generally applied to every assemblage of bodies in such a manner that the movement of any point whatever causes the movement of all the others.

The pantograph, the parallelogram of Watt, etc., are such assemblages, and may be considered as compound compasses.

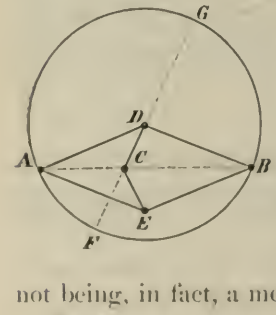
Apparatuses of this kind possess the valuable advantage of requiring very small forces to put them in motion, and their displacements are continuous and perfectly regular, by reason of the possibility of completely suppressing all play in the articulations.

They have neither irregularities nor "lost motion," to speak technically.

These diverse properties specially recommend them to the constructor of instruments of precision, and we shall adopt them exclusively for the object that we have in view, that is to say, the mechanical tracing of plane curves.

The line that starts from any point whatever, guided by a combination of articulated pieces, is necessarily algebraical. Reciprocally one perceives that all algebraical curves can be generated by a properly arranged articulated system, because one will always have at command a sufficient number of variable elements, radii and centres of rotation to be able to satisfy the equations expressing the identity between the given curve and the described one.

Fig. 1.



In what follows, we will limit ourselves to compound compasses tracing the best known lines, the straight line, the circle of any radius, the conic sections, and lastly conchoids and cissoids.

We shall present the result of our researches in a synthetical form, the analytical processes which have guided us in the most interesting part of this work, that relative to the straight line being very complicated, and not being, in fact, a method of investigation sufficiently methodical.

Lemma.—Any point whatever, C, Fig. 1, taken upon the diagonal of a lozenge, divides it into two segments of which the product $\overline{AC} \times \overline{CB}$ is equal to the difference $\overline{AD}^2 - \overline{CD}^2$ between the squares constructed upon the side of the lozenge and upon the distance $\overline{CD}$ of the point considered from the extremities of the other diagonal.

Prolong $\overline{CD}$ till it cuts in F and G the circle described from the point D as a centre with the radius $\overline{DA}$.

We have

$$\overline{AC} \times \overline{BC} = \overline{CF} \times \overline{CG} = (\overline{AD} - \overline{CD})(\overline{AD} + \overline{CD})$$
$$= \overline{BD}^2 - \overline{CD}^2$$

This remarkably simple demonstration has been given to us by M. Mannheim.

It follows then that if one supposes that the figure $EADBECD$ represents an assemblage of rigid rods articulated at their extremities, and that the point C remains fixed, the opposite extremities, A and B, will describe reciprocal curves. This combination will form the essential organ of the divers compound compasses that we shall have to examine.

1st. The reciprocal of a straight line being a circle passing through the pole, if the point B (Figs. 2 and 3) is forced to move in the perimeter of a circle passing through the centre of articulation C, the movement of the point A will be rectilinear. It will therefore suffice, in order to generate a straight line, to introduce in the mechanism $EADBECD$ a new fixed centre, C', to which one fastens the point B, the link $\overline{C'B}$ being equal in length to the distance $\overline{CC'}$ between the fixed centres.

Fig. 2.

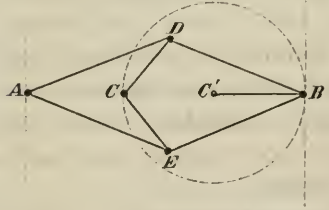
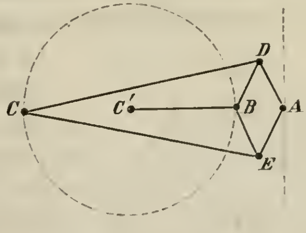


Fig. 3.



What precedes constitutes a rigorous solution of the problem stated by Watt. It is simple enough to be advantageously employed in certain machines of long stroke.

Mr. Mannheim, in 1867, made it the subject of a communication to the Société Philomathique of Paris

2d. If the circle described by the vertex B does not pass through the fixed centre C, the opposite vertex A describes a circle whose radius is represented by the expression

$$R = \frac{(a^2 - b^2)r}{r_2 - d^2}$$

in which one designates by a the side of the lozenge $\overline{AD}$; b the bridle rod $\overline{CD}$; r the radius $\overline{C''B}$; d the distance between the centres CC''.

If $r = d$ we have $R = \infty$ which corresponds to the case of a straight line.

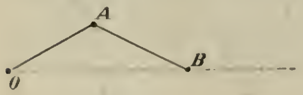
This combination of articulated pieces will then permit, if we vary one of the elements, for example the distance CC', the tracing of arcs of circles of every curvature in a continuous manner.

Designers know that this operation, apparently so simple, is not less complicated than the tracing of any geometric curve whatever, when it happens to be a curve surpassing the extreme limits of the beam compass.

3d. Let us now consider the conic sections.

We know there exists an infinity of theorems leading to their determination by means of the straight line and the circle, if successive points of these lines are given. Of the articulated systems coming in question, permitting so to say, the materializing of every combination of straight lines and of circles, without recourse to other organs of transmission, have articulated rods, we foresee that there ought to exist an infinity of compound compasses adapted to the tracing of lines of the second order.

Fig. 4.



Thus a finite straight line, AB, of the same length as OA, Fig. 4, being moved, for example, with its extremities in the circumference of a circle, and upon one of its diameters, $\overline{OB}$, each point of the movable line will describe an ellipse. This theorem furnishes a very simple means of constructing an elliptic compass, since we are able to guide the straight line $\overline{AB}$, by its extremities as the data of the problem require.

But there is a more general solution, capable, by means of the same combination of lines, of describing all the conic sections without distinction.

The polar equation of these curves is

$$\rho = \frac{p}{1 + \varepsilon \cos. \omega}$$

and represents ellipses, parabolas or hyperbolas, according as $\varepsilon < 1$; $\varepsilon = 1$ or $\varepsilon > 1$.

If we consider the reciprocal curve of the preceding, we will have for the equation

$$\rho^1 = \frac{k^2 (1 + \varepsilon \cos. \omega)}{p}$$

k being a constant. It is a limaçon de Pascal, of which we shall describe the mechanical generation.

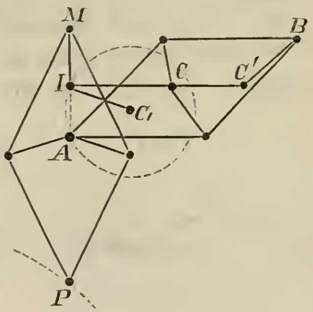
For this, let us return to the compass relating to the straight line, to which we will add the bridle rod, $\overline{C_1 I}$, Fig. 5, where the straight line described by A cuts the line of centres CC'. If we fix the point C_1 as well as the vertex A, and make $C_1 I = C_1 A$, and let all the other points of the figure remain free, it is apparent that any point M of the perpendicular IM to CC'' will describe a limaçon de Pascal. Of which the equation will be

$$\rho^1 = 2\, \overline{C_1 I} \cos. \omega + IM$$

Its reciprocal relatively to A is a conic.

We shall obtain this latter curve by connecting the point M to the free vertex of an articulated system whose fixed centre is A.

Fig. 5.



This point will become the focus of the conic of which $\overline{AC'}$ will be the direction of the principal axis, and which will be

$$\left.\begin{array}{l}\text{An ellipse,}\\ \text{A parabola,}\\ \text{A hyperbola,}\end{array}\right\} \text{if } \frac{IM}{2C_1 I} \left\{\begin{array}{l}< 1\\ = 1\\ > 1\end{array}\right.$$

It is besides evident that by giving to IM and to $C_1 I$ convenient values it will be possible to trace with the same compound compass all the curves of the second degree.

Conchoids of the Circle and of the Straight Line, Cissoid, etc.

We have just seen how one is able to arrange for tracing the conchoid of the circle, or limaçon de Pascal; by modifying the combination relative to this curve in a similar manner to that pursued for the conics we shall generate the conchoid of the straight line. We find in the same manner the combinations suitable for the lemniscata, but they are for the most part very complicated. We shall content ourselves, in closing this short summary, by indicating the compass for the cissoid, which is extremely simple. The centre of articulation of the links $\overline{CD}$ $\overline{CE}$ (Fig. 6) is forced to move in circle passing through the fixed vertex A of the lozenge, whose diameter is equal to $\sqrt{b^2 - a^2}$.

As before, b designating the length CD and a the length AD.

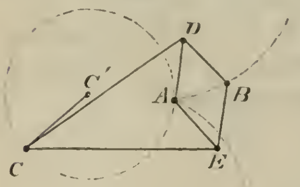
The opposite vertex B under these conditions will trace the cissoid, as is easy to see by forming the equation of the described curve.—*End of translation.*

This translation is made with the desire that the fortunate inventor of this remarkable linkage be awarded by English readers the credit justly his due; not only as an inventor but as a mathematician capable of understanding and discussing his invention in an able manner.

Referring to Fig. 1 and, for the sake of brevity, designating the radii vectores AC by ρ^1, BC by ρ and the constant $\overline{AD}^2 - \overline{CD}^2 = a^2 - b^2$ by m^2, called the modulus of the linkage, we have

$$\rho\rho^1 = m^2 \tag{1}$$

Fig. 6.



Referring to Figs. 2 and 3, Section 1, we see that the fixed centre C'', midway between B and C and the radius bar $C''B$, forces the vertex B to move in the perimeter of a circle passing through the pole C (fixed point), the prime radius of which is its diameter. This gives

$$\rho = 2\ r \cos.\ a$$

in which $r = CC'' = C''B$ and $a =$ the angle through which the point B is moved with respect to the fixed line ACB. Substituting this value in Equation (1), we have

$$\rho^1 = \frac{m^2}{2\ r\ \cos.\ a} = \frac{m^2}{2r} \sec.\ a \tag{2}$$

Which is the polar equation of a straight line at right angles to the prime radius ABC, and we see that the point A will describe a straight line.

The form of cell outlined in Fig. 2 is commonly called a negative cell, and that in Fig. 3 a positive cell.

Referring to Section 2, and using the notation there given, we have for any position of C'' between B and C

$$\rho^2 - 2\,d\,\rho\cos.\,a = r^2 - d^2$$

$$\rho = d\,\cos.\,a \pm \sqrt{r^2 - d^2\sin.^2 a} \tag{3}$$

Substituting for ρ its value $\frac{m^2}{\rho^1}$ we have

$$\frac{m^4}{\rho^{12}} - \frac{2\,d\,m^2}{\rho^1}\cos.\,a = r^2 - d^2 \text{ and reducing}$$

$$\rho^1 = -\frac{m^2\,d}{r^2 - d^2}\cos.\,a \pm \sqrt{\left(\frac{m^2\,r}{r^2-d^2}\right)^2 - \left(\frac{m^2\,d}{r^2-d^2}\right)^2\sin.\,a} \tag{4}$$

If in this equation we place

$$D = \frac{m^2 d}{r^2 - d^2} \text{ and } R = \frac{m^2\,r}{r^2 - d^2}$$

Equation (4) becomes

$$\rho^1 = D\cos.\,a \pm \sqrt{R^2 - D\ \sin.^2 a} \tag{5}$$

and we observe that Equations (3) and (5) are similar; therefore while the vertex B describes an arc of a circle as stated with the radius r and centres at a distance, d, from the pole C, the vertex A will describe an arc of a circle whose centre is on the prime radius at a distance, D, $= \frac{m^2 d}{r^2 - d^2}$ from the pole C' with a radius

$$R = \frac{m^2\,r}{r^2 - d^2} = \frac{(a^2 - b^2)\,r}{r^2 - d^2} \tag{6}$$

If we make the distance between B and C (Figs. 2 and 3) constant and $= 2\ e$, and denote the distance of the point C^1 from a point bisecting the line BC by x, we can simplify this equation.

Let $d = e \pm x$

" $r = e \mp x$

We have $R = \frac{m^2\,r}{r^2 - d^2} = -\frac{m^2(e - x)}{4\,e\,x}$ or $= \frac{m^2(e + x)}{4\,e\,x}$

Still further reducing, we have for the value of x

$$+\,x = \frac{m^2}{\frac{m^2}{e} + 4\,R} \tag{7}$$

$$\text{or } -\,x = \frac{m^2}{\frac{m^2}{e} - 4\,R} \tag{8}$$

since in the latter case R is of the contrary sign.

We have now a ready means of computing the distance x to the right or left of the central point of the line BC, in order to describe an arc of any required radius, R.

When x is $+$, *i. e.*, moved to the right, the arc is convex to the pole C, and Equation (7) should be used; when $x = 0$ we have an arc of infinite radius, a straight line; when x is $-$, *i. e.*, moved to the left, the arc is concave to the pole C, and Equation (8) should be used in computing the radius.

The compound compass shown in Fig. 7 is adapted to drawing arcs of a little over 3 feet in length.

The construction will, in the light of previous explanations, be readily understood; in it we have taken $a = 12$ inches

$$b = 8 \text{ “}$$
$$2\,c = 12 \text{ “}$$
$$\text{giving } m^2 = 144 - 64 = 80$$

This will be found a most convenient size for the ordinary purposes of the draughtsman.

At C^1 is a split joint, such as is used for proportional dividers, and the vertex B is steadied by means of a hole and pin while the joint is being adjusted at any required distance from C^1, this joint sliding in the slots in the radius bar C^1B and the ruler CB. A scale reading to hundredths of an inch is laid off from the central point C^1 three inches both ways.

The better method of locating the mid point C^1 is to adjust it tentatively until the vertex A describes a perfectly straight line. The following table of values of x for circles of radii between 10 and 120 inches has been computed by means of Formulæ (7) and (8), which reduce to

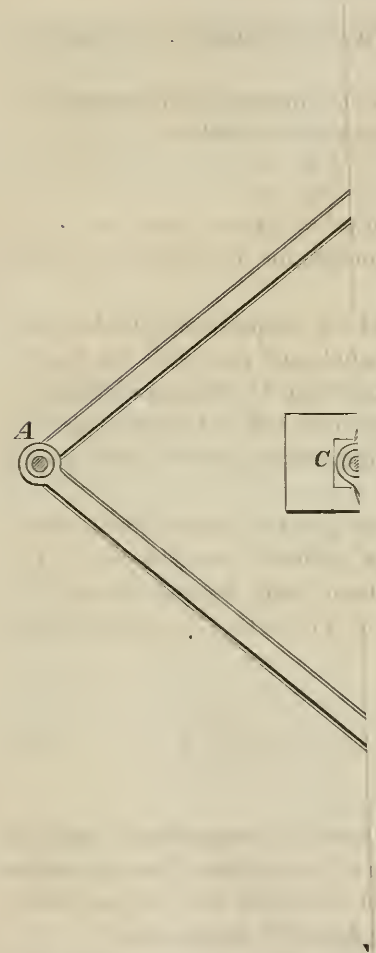
$$\pm x = \frac{60}{10 \pm 3\,R} \qquad (9)$$

and can be used for computing the value of x for circles of any radius from $3\frac{1}{3}$ inches to infinity or a straight line, with an instrument of the described proportions.

Radius	Convex arcs $+x =$	Concave arcs $-x =$
10 in.	1·500	3·000
20 “	0·857	1·200
30 “	0·600	0·750
40 “	0·462	0·545
50 “	0·375	0·428
60 “	0·316	0·353
70 “	0·273	0·300
80 “	0·240	0·261
90 “	0·214	0·231
100 “	0·194	0·207
110 “	0·177	0·188
120 “	0·162	0·171

In order to use the instrument, place the ruler CB on any normal to the circle, adjust the joint at the required distance x and cause the pencil in the vertex A to coincide with the starting point of the circle sliding the ruler upon the normal until the proper position is reached. The circle can then be described.

Referring to the special elliptic linkage, Section 3 of Peaucellier's paper Fig. 4, if $OA = AB$, we have Fig. 8, $r = OA = AB$ and $d = AP$ and



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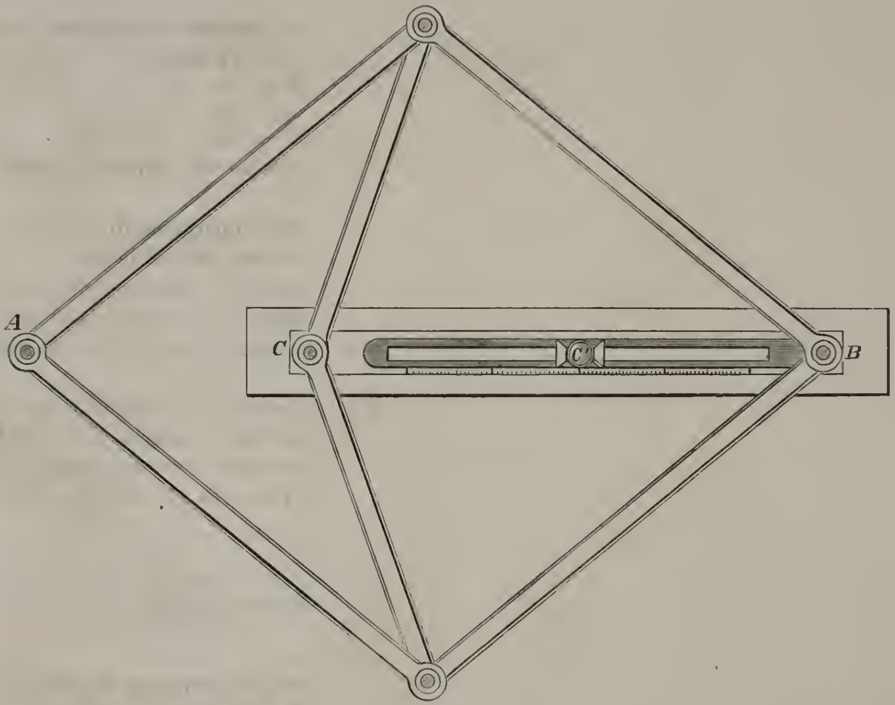
and reducing

$$y^2 = \frac{(l-d)^2}{l^2}\,(2\,rx - x^2) \qquad (12)$$

which is the equation of an ellipse referred to its vertex and of which the major and minor semi-axes are r and $\frac{l-d}{l}\,r$.

Fig. 7.



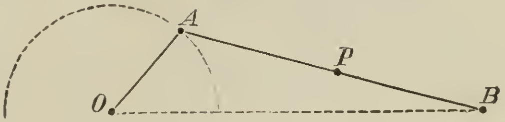
Referring to the special elliptic linkage, Section 3 of Peaucellier's paper Fig. 4, if $OA = AB$, we have Fig. 8, $r = OA = AB$ and $d = AP$ and

$$y^2 = \left(\frac{r-d}{r+d}\right)^2 \left(2(r+d)x - x^2\right)$$

the equation of an ellipse referred to its vertex of which the transverse and conjugate semi-axes are $(r + d)$ *and* $(r - d)$.

The case is different when AB is greater than OA and of interest, as covering the ordinary instance of a point on a connecting rod which describes an egg-shaped oval closely approximating to an ellipse.

Fig. 8.



The equation of the curve described by a point P at a distance d from A on the line AB, Fig. 8, when referred to rectangular co-ordinates with the origin in the perimeter at a distance $(r + d)$ from O, and with OB for the axis of abscissas is, representing AB by l; OA by r.

$$x = r + d - \frac{\sqrt{r^2(l-d)^2 - y^2 l^2} + \sqrt{d^2(l-d)^2 - d^2 y^2}}{l-d.} \qquad (10)$$

For $d = 0$ we have $y^2 = 2rx - x^2$ the equation of a circle with the radius r.

For $d = l$ we have $x = \infty$ which is the equation of a straight line coinciding with the axis of abscissas.

If we cause equation (10) to take the form

$$x = r\left(1 - \sqrt{1 - \frac{y^2 l^2}{(l-d)^2 r^2}}\right) + d\left(1 - \sqrt{1 - \frac{y^2}{(l-d)^2}}\right) \qquad (11)$$

and neglect the last term as inconsiderable when d is relatively small or l very great, we have

$$x = r - \sqrt{r^2 - \frac{y^2 l^2}{(l-d)^2}}$$

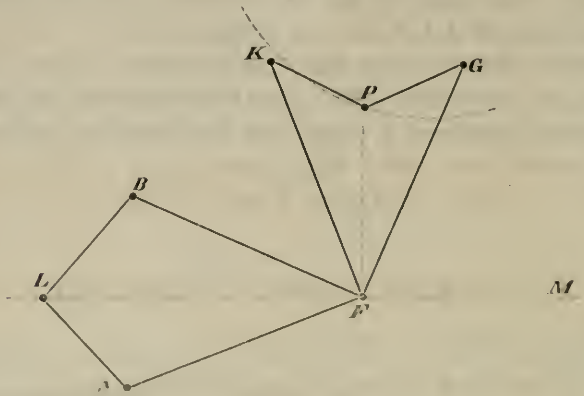
and reducing

$$y^2 = \frac{(l-d)^2}{l^2}(2rx - x^2) \qquad (12)$$

which is the equation of an ellipse referred to its vertex and of which the major and minor semi-axes are r and $\frac{l-d}{l}r$.

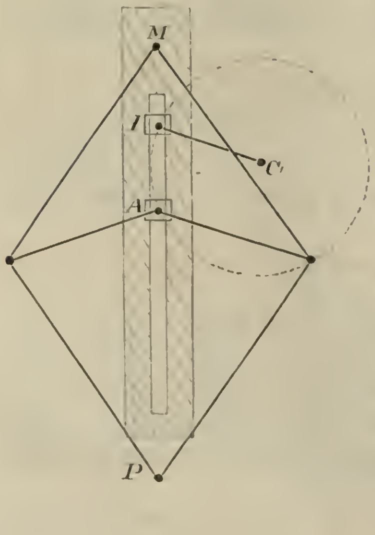
The special linkage shown in Fig. 9 was devised by Mr. Freeland, University of Pennsylvania, and will describe a hyperbola, it is a positive cell having the longer arms split and turned through a fixed angle, being fastened together at F, the arm AFK forming one piece, and the arm BFG another. The point L being fixed, the point F is forced to move along the straight line LM, the point P will describe a hyperbola. The equation $\rho\rho^1 = m^2$ being that of a hyperbola referred to its asymptotes. In this case $m^2 = \frac{A^2 + B^2}{4}$, and A and B are the major and minor semi-axes of the hyberbola.

Fig. 9.



The limaçon of Pascal is a curve traced by a point on a line which projects a constant distance beyond the circumference and passes through a fixed point on the circumference of a circle.

Fig. 10.



In the combination of linkages shown in Fig. 5, the function of the cell ACC^1B is by means of the bar C^1CI to cause the prolongation of IM to pass through the point A in all its positions, as IM is rigidly fastened to ICC^1 and at right angles to it. In this linkage, the only points fastened to the surface, upon which these two linkages move, are A and C.

This assemblage, although theoretically fulfilling the required conditions, is too complicated for ordinary purposes.

A good mechanical substitute is shown in Fig. 10, which is lettered as in Fig. 5. The place of the cell $A\,C\,C^1 B$, Fig. 5, is supplied by the slotted ruler $M\,I\,A\,P$, and the radius bar $C_1\,I$. The same cell may be used as that shown in Fig. 7, the alteration required being in the ruler used as a basis. The pin C_1 is fixed and the radius bar can be made adjustable at I in the slot $I\,A$, and to any length. The point A is fixed, the slotted ruler sliding upon it. The point M is fastened to the ruler. The point P will describe conic sections as in Fig. 5.

$I\,M = \frac{m^2}{p}$, m being the modulus of the cell and $p =$ the semi-latus rectum or half the principal parameter.

$C_1 I = \frac{m^2\,\varepsilon}{2p}$ in which $\varepsilon =$ the eccentricity of the conic section.

We have now a ready mechanical means of describing any required straight line, circle, ellipse, parabola or hyperbola as the case may require.

Letting $A =$ the transverse and $B =$ the conjugate semi-axes, we have for an ellipse

$$I\,M = \frac{m^2\,A}{B^2} \text{ and } C_1\,I = \frac{m^2\sqrt{(A^2 - B^2)}}{2\,B^2}$$

For a hyperbola

$$I\,M = \frac{m^2\,A}{B^2} \text{ and } C_1\,I = \frac{m^2\sqrt{(A^2 + B^2)}}{2\,B^2}$$

For a parabola

$$I\,M = \frac{m^2}{p} \text{ and } C_1\,I = \frac{m^2}{2\,p}$$

Referring to the linkage for the cissoid, Fig. 6, we have

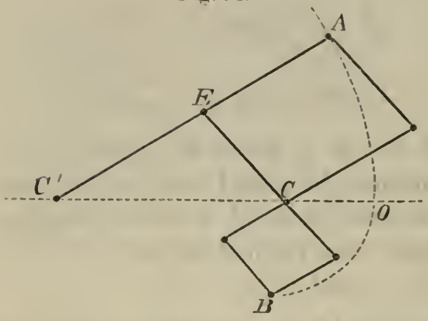
$$AB = CB - CA = \frac{m^2}{CA} - CA\text{ ; or,}$$

$$\rho = \frac{m^2}{\rho^1} - \rho^1 = \frac{m}{\cos.\ a} - m\cos.\ a = m\,\frac{\sin.^2\ a}{\cos.\ a} = m\sin.\ a\tan.\ a$$

which is the polar equation of the cissoid under the condition placed

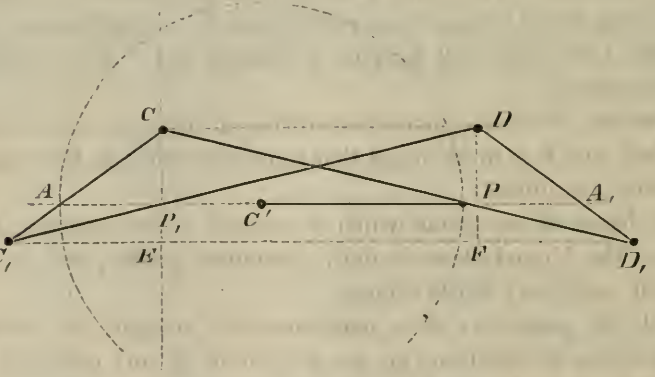
$C^1 A$, being the polar axis and m the diameter of the circle passing through A of a radius $= C^1 A = \frac{m}{2}$.

Fig. 11.



In Fig. 11 (this figure is distorted, each parallelogram should be a rhomb) is shown an ingenious adaptation of a linkage to the tracing of ellipses due to Mr. Freeland, student in this University. The point C^1 is fixed, the point C is forced to follow the straight line C^1CO, $C^1E = EA = EC$. The point A traces a circle of the radius C^1A, and the point B traces an ellipse OB. The point opposite to E in the large rhomb and the two unlettered points in the other, also describe ellipses.

Fig. 12.



We will close this brief essay by an explanation of Hart's Perfect Parallel Motion, which is described by Mr. Kempe in "How to Draw a Straight Line."

This linkage is remarkable, because only four rods are required where six are used in Peaucellier's cell. It will be perceived that this linkage CD_1DC_1C is a parallelogram in a reversed position, *i. e.* the rods CD_1 and C_1D instead of being parallel are crossed (Fig. 12).

Let a straight line AP_1PA_1 be drawn parallel to C_1D_1, cutting all the links in AP_1PA_1.

Let $AP = \rho$
" $AP_1 = \rho^1$
" $AC_1 = a_1$
" $AC = a_2$
" $CD = b$
" $C_1D_1 = b_1$
" $CC_1 = a_3$
" $C_1E = D_1F = d$
" $CE = DF = h$
$C_1D = b_3$

The similarity of the triangles CC_1D_1 and CAP and also C_1CD and C_1AP_1 which is true for all positions gives the two proportions

$$\frac{\rho}{b_1} = \frac{a_2}{a_3} \text{ and } \frac{\rho^1}{b} = \frac{a_1}{a_3}$$

$$\text{Therefore, } \rho\rho^1 = \frac{a^1a^2}{a_3^2} bb_1$$

But $bb^1 = b\,(b + 2d) = b^2 + 2bd.$

From the right angled triangles C_1FD and C_1EC we have $(b + d)^2 + h^2 = b_3^2$ and also $d^2 + h^2 = a_3^2$, subtracting the latter from the first we have

$$b_3^2 - a_3^2 = b^2 - 2\,bd = bb_1$$

$$\text{Therefore, } \rho\rho^1 = \frac{a_1\,a_2}{a_3^2}\,(b_3^2 - a_3^2) = m^2.$$

All the terms of the second member of this equation being constants, we have a linkage with the same properties as the Peaucellier Compound Compass. The point A being fixed and either of the points P or P_1 being forced to move in a circle with the circumference, passing through A the other will describe a straight line. These points are interchangeable.

There are, of course, many other forms of linkages besides the ones described, and it is to be hoped that some mentioned in this paper can be greatly simplified.

The degree of exactitude which is required in the mechanical workshops of the United States is daily becoming greater, and at present tries our machinery to the utmost.

With the possibility of a mathematically straight line before us, with a means of describing an arc of a circle of any radius, in a convenient shape, and with the conic sections almost as easily describable as a circle; there is no reason why our mechanics should not produce machinery of an exactitude, and in forms hitherto deemed unattainable.

University of Pennsylvania, February 18th, 1879.

Wealth of France and England.—The national wealth of England is estimated at $39,200,000,000, that of France at $40,300,000,000.—*Fortsch. der Zeit.*

THE DRIVING POWER OF LEATHER BELTS.

By Robert Briggs, C. E.

In the Journal of the Franklin Institute for May will be found a translation of a paper on leather belts, which paper appeared in a communication to the Industrial Society of Mulhouse, in May, 1835. The following is the basis of the paper:

"The science of applied mechanics gives the formula relating to this subject as follows: Calling

P, the resistance to be overcome,
e, the base of Naperian logarithms,
f, the coefficient of friction of leather upon cast iron,
R, the radius of the pulley,
S, the length of the arc of contact.

"The formula is written thus:

$$\text{Friction} = P\left((e)^{\frac{fS}{R}} - 1\right)$$

*   *   *   *   *   *

It is late to correct an erroneous deduction of forty-four years since, but as the paper is resuscitated with the evident purpose of showing or comparing the applicability of its results to present use, it is yet necessary to show that the whole article was founded on a mistake.

Adopting the formula in its present shape of

$$\text{Friction} = P\left((e)^{\frac{fS}{R}} - 1\right)$$

It will be found there should be placed for the word "Friction" some letter or character which should express the difference of tension between the tight and the slack side of the belt, that is the effective pull of the belt, and the value for P is that of the tension on the slack side of the belt.

The correct formulæ are:

Calling T_1 = tension on tight side of belt,
T_2 = " " slack " " "
P = effective pull on the belt $= T_1 - T_2$.

Then the "science of applied mechanics"* gives:

$$\frac{T_1}{T_2} = e^{\frac{fS}{R}}$$

$$P = T_1 \left(\frac{e^{\frac{fS}{R}} - 1}{e^{\frac{fS}{R}}} \right)$$

$$P = T_2 \left({}^{\frac{fS}{R}} - 1 \right)$$

The last of these formulæ is evidently that used by Mr. Heilmann. The capability of the belt is manifestly its strength to resist the tension T_1 on the tight side of the belt, and consequently the figures of comparison of ratio of the effective pull to the tension on the slack side of the belt (which are those given in the paper) possess no practical value whatever.

While calling attention to the mistaken use of formula in this computation, it may be proper to show what would have proceeded from correct use with the data accepted by M. Heilmann; taking Moran's coefficient of friction and M. Laborde's table of force exerted by pulleys with 180° contact. When the ratio of effective force = P to the tension on the tight side of a belt = T_1 for different angles of contact; for 0·122 frictional adhesion of belt to pulley becomes:

Angles	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	360°
$\frac{P}{T_1}$	= 0·0619	= 0·0994	= 0·1744	= 0·2255	= 0·2734	= 0·3184	= 0·3605	= 0·4001	= 0·4371	= 0·4721	= 0·5047	= 0·5354

These figures give the multipliers of widths of belts as given in M. Laborde's tables for various angles of contact.

= 5·344 = 3·203 = 1·826 = 1·431 = 1·165 = 0 = 0·883 = 0·796 = 0·728 = 0·674 = 0·631 = 0·595

The above figures, however, possess only the merit of accurate computation; not having the least of use, as the coefficient of friction on which they are based is three and a half times too small for conformity with any practice.

It will be noticed that the paper assumes a value for *f*. "The ratio of friction to pressure for leather upon plane surfaces of cast iron has been taken from the experiments of M. Morin." A simple retrograding computation finds from the tables this assumed value to have been 0·122. Direct experiments, which can be repeated by any mechanic at any moment, have shown this ratio to be as large as 0·58 under favorable conditions, and that over 0·40 can be accepted as the *hold* of the belt in general practice.

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* "Rankine's Applied Mechanics," p. 618; the same will be found in any work on applied mechanics.

In the JOURNAL (volume CVI), November, 1878, p. 309, the comment upon M. Laborde's paper computes the strain on the belts accepted as a basis by M. Laborde at 19·15 pounds per inch of width. This computation makes no distinction between the strain on the tight side of the belt and the *effective* strain on the same side accepted by M. Laborde as the measure of imparted force. If the friction of a belt on its pulley be taken at 0·42 and the angle of contact 180°, then the tension on the tight side of a belt exerting an effective pull of 19·15 pounds is 26·26 pounds and the tension on the slack side will be 7·11 pounds.

It may be well to recapitulate a table which was given some years since in the JOURNAL OF THE FRANKLIN INSTITUTE.*

Maximum strain on belting 66⅔ pounds per inch of width; coefficient of friction single leather belts on iron pulleys, 0·42.

Arc of contact,	90°	100°	110°	120°	135°	150°	180°	210°	240°	270°
Strain transmitted (pounds),	32·36	34·80	37·07	39·18	42·06	44·64	49·01	52·53	55.34	57·58
Tension, loose side,	34·31	31·87	29·60	27·49	24·61	22·03	17·66	14·14	11·33	9·09
Total tension on belt,	100·98	98·54	96·27	94·16	91·28	88·70	84·33	80·81	78·00	75·76
Strain between axes of pulleys derived from the belt when at work,	71·40	75·94	78·85	81·54	84·32	85·68	84·33	78·07	67·55	53·56
Tension on each side when at rest,	50·49	49·27	48·14	47·08	45·64	44·35	42·17	40·41	39·00	37·88

The last line shows how tight a belt must be made in order to give out its maximum strain of 66⅔ pounds per inch of width when at work.

Telegraphic Announcement of Freshets.—The minister of public works is experimenting upon the Lot, in the Department of l'Arveyron, with an electric apparatus for producing an automatic record of the variations in the level of rivers, so as to signal the occurrence of freshets as soon as they arise, in order to give the inhabitants of the river banks as much time as possible to ward off the danger. The apparatus employed is similar to one that was invented by one of the government engineers who is in the Algerian service. Professor Codazza, Sig. Cabella and Professor Ferrini have also devised indicators for the same purpose.—*L'Electricité; Il Politecnico.*

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* January, 1868.

SOME EXPERIMENTS ON ALLOYS OF SILVER WITH EMBRITTLING METALS.

Made at the United States Mint, Philadelphia,

BY

ALEXANDER E. OUTERBRIDGE, JR.

It is a fact very well known to metallurgists that the presence of certain base metals in refined gold and silver, even in such small percentages as to render their detection difficult, if not impracticable, by ordinary chemical tests, will nevertheless exercise such an injurious effect in regard to ductility, hardness, etc., as to render the metal totally unfit for coin or the industrial arts, thereby necessitating the removal of these impurities by oxidizing fluxes, or other equivalent means.

It is also well established that during the process of removing these impurities (technically called "toughening"), an inevitable, though variable, loss occurs.

This loss may be directly traced to three causes:

First. To the formation of volatile compounds of gold or silver with the baser metals.

Second. To the violent action on the surface of the metal during the decomposition of the oxidizing agent, thereby causing minute particles of the molten metal to be sprayed from the surface.

Third. To the upward current of air and flame sweeping over the surface of the molten metal in the pot drawing into the flue the vaporized metal and the fine spray.

These vapors are carried by the strong draught of the wind furnace out of the chimney, where they partially fall, in a sort of fine rain, upon the roof of the Mint and neighboring buildings, and a larger portion is carried into free space and lost.

Attempts have been made to recover the metal thus dissipated by means of shelves and other devices arranged in the flue, with but partial success, and they have the practical disadvantage of tending to impair the draught in the wind furnace.

It was to overcome these difficulties that an apparatus was devised by the writer to prevent the metallic vapors and gases arising from the melting-pot from escaping into the flue at all by drawing them off into a suitable condensing chamber.

The Chief Assayer of the Mint, after examining the drawings, laid the whole matter before the late Director of the Mint in Washington, who in turn instructed the writer to have an experimental apparatus constructed, and "after it is finished to have it thoroughly tested by careful trials under the direction of the Melter and Refiner."

In accordance with these instructions the apparatus was made and erected at one of the furnaces in the melting department, and the trial tests were commenced on February 5th, 1878, and continued as opportunity offered until they were suspended, owing to the unprecedented increase in the regular work consequent upon the passage of the Bland Silver bill.

The arrangement of the experiments having been entrusted to the writer, he prepared a schedule of the proposed work, which was approved by the officers directly interested. It was designed by the writer that these trial melts should also subserve a broader purpose of furnishing reliable data as to the relatively injurious effects upon refined silver of small but known percentages of such base metals as were supposed to impair its good qualities. It is this secondary portion of the work which is now submitted, albeit in an incomplete form, to the readers of the JOURNAL OF THE FRANKLIN INSTITUTE.

The schedule as far as completed includes the preparation and subsequent examination, analysis and refining, of alloys of silver with arsenic, antimony, bismuth and lead.

About one thousand (1000) ounces of silver was adopted as the normal weight of refined metal to each experimental melt.*

With respect to the success of the apparatus, the writer desires merely to refer by permission to the brief extracts from letters of the officers, who observed its operation, which accompanied his report made to the late Superintendent of the Mint. These will be found in the foot note.†

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* Although the assay department long since adopted the French system of weights, viz., the gramme and its decimals, the troy ounce is still regarded as the unit or standard Mint weight, and is accordingly employed in these experiments.

† Professor Booth, the Melter and Refiner, in whose department the tests were made, after endorsing the accompanying report as expressing the results of the trials in their integrity, says, "In relation to the TRIAL OF APPARATUS, I remark that the principle underlying Mr. Outerbridge's process is sound, viz., to recover volatilized precious metals by drawing off the possible vapors above gold and silver in a crucible and

He also desires to say that the credit for the success which attended the tentative tests of the apparatus is largely due to the excellent suggestions in the mechanical details which were made by Mr. Samuel James, the Master Mechanic of the Mint, to whom was entrusted the construction of the machine, thereby materially improving the original design.

FIRST EXPERIMENT—SILVER ALLOYED WITH ARSENIC.

Although the metal arsenic has a great affinity for silver, it will not readily combine with it in an open crucible, owing to its extreme volatility. The following expedient was therefore resorted to, with success:

A bar of silver which assayed 999 thousandths fine and weighed 100·46 ozs. (troy) was first melted with 3 ozs. of metallic arsenic in a black lead pot, with a lid luted on with fire-clay, and bound tightly with a metal strap.

The fire was brought up gradually for two hours, then a good white heat for half an hour; it was then allowed to slowly die out; the crucible remaining in its place was agitated in order to bring fresh surfaces of the molten silver in contact with the confined vapors of arsenic. A lump of charcoal was put in the crucible to prevent oxidation of the arsenic. When the pot was cold the "king" of metal was broken out, cleaned and weighed. It turned the scale at 102·98 ozs., showing that 2·52 ozs. of arsenic had combined with the silver.

The exterior surface of the "king," as it is technically called, presented a light grey color. On breaking it open this light shade was observed to extend to a depth of about $\frac{1}{20}$th of an inch; the interior showed a darker grey color, indicating that the surface contained a smaller proportion of arsenic. In order to ascertain this a piece was assayed from the surface and another from the interior, with the following result:

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wholly condensing them. I remark further that his mode of effecting the result is, I believe, new, simple, effective and inexpensive," etc.

Mr. Wm. E. DuBois, the Chief Assayer, after alluding at some length to the evils which the apparatus was designed to overcome, says: "These two points being kept in view by all concerned, it was interesting to observe the changes and modifications by which the system (as all systems are) was step by step improved and simplified, until it seems nearly complete. Certainly it is now in such a satisfactory shape as would warrant its introduction into the mints and assay offices and refineries generally; for it is well known that the evil which it abates is not confined to this institution."

Surface, ...	975 fine.
Interior, . . .	971 fine.

It is possible that the portion of the metal touching the sides of the pot remained hot somewhat longer than the centre, owing to the fact that the pot remained in the fire until the whole had cooled. The volatile arsenic may thus have been driven (or distilled) *in* to the central portion of the solidifying mass.

The broken surface of the metal presented a clearly crystalline structure, and, although by no means so ductile as fine silver, it was far more so than could have been anticipated. The metal hammered and rolled without splitting. The solution in nitric acid was perfectly clear like fine silver, and no trace of arsenic could be detected by the eye or smell. Two samples of the alloy were preserved for future comparisons; one was rolled into a ribbon, to show the malleability; the other broken, to show the fracture.

In the next operation, 952 ozs. silver, 999 fine, were melted in a No. 40 black lead crucible. When the fine silver was perfectly fluid, the king of silver-arsenic alloy weighing 102·29 ozs., was added to the mass; the metal was then stirred and a sample for reference extracted

The metal was finally toughened in the ordinary way, using nitre and sand. At the end of one hour and a half the flux was skimmed from the surface and the metal poured into large shoe moulds.

The sample taken from the mass after the "king" was thoroughly incorporated, assayed 995¼, which agreed closely with the theoretical fineness, viz., 996. This sample was reserved for future experiments.

The mass metal, after having been toughened as above stated, was cast into bars, and assayed 998. The metal was then perfectly ductile, and no trace of arsenic could be detected by the eye.

The sweep resulting from the grinding of the crucible weighed 28½ lbs. avoirdupois, and contained 97·712 grs. of pure silver per pound avoirdupois. The sweep from the grinding of the ashes in the furnace weighed 58 lbs., and contained ·720 of a grain per lb. The entire weight of silver in both sweeps was thus found to be 1·12 oz. troy.

SECOND EXPERIMENT—WITH ANTIMONY.

The toughened silver resulting from the previous experiment was manipulated in the following way:

One bar, 998 fine, weighing 119·60 ozs., was melted in a closed crucible with 3 ozs. of metallic antimony, with the addition of charcoal to prevent oxidation. The pot was allowed to cool slowly (as in the previous experiment with arsenic), and the king of alloyed metal resulting was found to weigh 122·39 ozs., showing that 2·79 ozs. of antimony had combined with the silver. The king assayed 975 fine, and contained 2½ per cent. of antimony.

The metal was remarkably tough and ductile, rolling almost as well as fine silver; fracture crystalline and coarse.

Next a melt of silver bars, 998 fine, weighing 786·08 ozs. (resulting from the silver-arsenic experiment), was melted in a No. 40 black lead pot, under charcoal. As soon as it was fluid the king of antimonic-silver alloy was added. The whole was thoroughly stirred and a sample cast out for future experiments. This sample assayed 994 fine.

The metal was now exposed to a hot fire for a period of one hour and a half, a current of air being allowed to pass over the surface. Nitre was added occasionally in small quantities for the purpose of burning off the charcoal. During the entire time, the antimonic-oxyd was seen rising to the surface of the metal, and burning off with quite copious fumes, passing up the condensing tube. The water in the glass condensing chamber became very turbid, and the filter soon clogged up with a heavy sediment. The toughened metal was then cast into bars, and assayed 998 fine, and presented all the characteristics of fine silver.

The material on the filter was dried and collected. It weighed 1·15 ozs. An examination under the microscope showed that it was profusely sprinkled with extremely minute globules of metallic silver. These particles are nearly perfectly spherical, conclusively proving that they have been volatilized and condensed. The majority of the globules were very much smaller than the interstices of the filtering cloth, thus leading to the inference that a portion of the silver may have passed through the wash water, and thus escaped into the well. This fact was conclusively proved in the next experiment by collecting some of the water percolating through the filter, allowing it to settle, and recovering a button of pure silver from the sediment.

An analysis of the material showed that it contained one-seventh ($\frac{1}{7}$) silver, the remainder being antimonic-oxyd, colored by charcoal dust. The filter was burnt, and added to the precipitate; the metal was reduced to a button and cupelled. It weighed $\frac{13}{100}$ ounce.

THIRD EXPERIMENT—WITH BISMUTH.

One bar of toughened silver (resulting from previous experiment) assaying 998, weighing 137·77 ozs. was melted in a closed (luted) crucible with 3 ounces of bismuth in the same manner as before. The king of alloyed metal weighed 140·73 ozs., showing that 2·96 ozs. of bismuth had combined with the silver. The king resembled exteriorly the antimonic-silver alloy, but on cutting into the metal, it was found (unlike the antimonic-silver) to be exceedingly brittle or "short" like pie-crust. The fracture presented a coarse grain with a lustreless or earthy surface. The color of the metal when hammered was very dark or leady, and the strips had a somewhat greasy feeling.

The sample assayed 975 fine, showing about 2½ per cent. of bismuth. A melt of 888·62 ozs. toughened silver, 998 fine, was then made in a No. 40 pot; as soon as it was melted the king was added. It was thoroughly incorporated with the mass by stirring; a sample was taken out and assayed 996 fine. The sample still showed plainly the "shortening" effect of bismuth; the fracture was crystalline and fine, the color was but slightly impaired and the assay slip rolled tolerably well.

The mass was now exposed to a high temperature for about three-quarters of an hour. Nitre was then added copiously, finally a small quantity of sand to thicken the flux just sufficiently to skim. The bars were cast into moulds, cleaned and weighed. On assaying the first and last bars it was found that but little or no improvement in fineness had occurred. The first bar assayed 996, the last 996½; they were consequently reported 996¼.

The difficulty was, according to Professor Booth, that the nitre being thin, failed to hold the oxyd of bismuth formed by its action. As soon as the oxygen (formed by the decomposition of the nitre) had been driven off, the reducing action of the black-lead pot caused the bismuth to go back to the metallic state, when it again formed an alloy with the metal. (This metal was afterwards refined to 999½ by the use of bone ash.)

As the examination of the precipitate collected on the filter in the previous experiment had revealed the fact that the volatilized silver globules were so minute as to lead to the inference that a portion had passed through the interstices of the filtering cloth, an effort was made to recover any particles thus escaping. The fact that the metal did so escape was conclusively proved in this experiment and a portion of the fugitive particles recovered. In this case, the water percolating through the filter was caught in a large iron tank, the overflow from this tank discharged into a second filter composed of two thicknesses of fine twilled linen. The water in the tank was allowed to remain at rest for several hours and then drawn off. On testing the sediment in the tank, it was found to be rich in silver; it was then dried, treated with carbonate of soda in a sand-pot. A button of silver was obtained which was purified by cupellation and then weighed ·07 of an ounce.

The sediment collected on the second filter was treated as above with a similar result. Finally a portion of the water escaping through the second filter was collected and silver was traced here also.

Although many of these particles or globules are so minute that a microscope with a good magnifying power is required to see them, they may be readily and beautifully exhibited by agitating a beaker-glass full of the water in the sunlight, when thousands of brilliantly scintillating points of light are seen reflected from the extremely minute faces of the silver pellicles. A similar effect is described by Faraday in "Philosophical Transactions," 1857. By treating very dilute solutions of gold with phosphorus he obtained the metal diffused through the liquid in extremely fine particles. These particles he says "are easily rendered evident by gathering the rays of the sun (or a lamp) into a cone by a lens, and sending the part of the cone near the focus into the fluid; the cone becomes visible, and though the illuminated particles cannot be distinguished, because of their minuteness, yet the light they reflect is golden in character and seen to be abundant in proportion to the quantity of gold present." He further says that portions of gold, in such a fine state of division that "they have not as yet been seen by any power of the microscope, may have the presence of the diffused solid particles rendered evident by the sun in this way."

SUPPLEMENTAL EXPERIMENT WITH THE SILVER BISMUTH ALLOY.

As already stated, the alloyed metal resulting from the experiment with bismuth was found to retain four and a half thousanths of bismuth which the nitre had not removed. In accordance with the suggestion of Professor Booth, the metal was again melted and covered with a coating of bone ash, holes were made in this covering with an iron poker and grains of nitre were dropped through to the exposed surface of the molten metal; as fast as the bismuth was oxidized it was absorbed and held by the bone ash (the principle being the same as in cupellation); at the end of about one hour, the bone ash was taken off, a fresh supply of nitre and sand added, the second flux skimmed off and the metal cast into bars. The condensing apparatus was not used, as it was supposed that the bone ash covering would protect the metal from volatilization. It was found, however, that a loss of 1·42 ozs. occurred. During the toughening, samples were taken out at intervals of twenty minutes and assayed; the first showed 997 the metal still remaining brittle. The second sample assayed 997¾ and was also brittle. The third assayed 999 and showed some brittleness, but the fracture presented a closer grain than in the two former samples. It was still quite unfit for coin ingot metal.

The bars when cast had all the appearance of fine silver, being perfectly ductile; they assayed 999½ fine. This result seems to indicate that small percentages of bismuth affect silver more injuriously, both in regard to its ductility and in respect to the difficulty of its elimination, than equal proportions of arsenic or antimony.

FIFTH EXPERIMENT—SILVER AND LEAD.

A bar of silver, 999½ fine, weighing 82·83 ozs., was melted under charcoal with 3 ozs. of pure lead in a closed crucible. The king of alloyed metal weighed 85·61 ozs., showing that 2·78 ozs. of lead had combined with the silver.

The exterior of the king had a white or frosted appearance. On cutting an assay chip, the metal was found to be very brittle, having a dull leaden color. The fracture was not very clearly crystalline, but seemed more like the effect of a mechanical tearing away of the metal. A similar effect was noticed in rolling and hammering the assay slip, for while it broke to pieces under the hammer, it seemed to be crumbly (like dry bread) rather than brittle. Under ordinary inspection, however, it would have been simply classed as brittle. The sample from the king assayed 960, or contained 4 per cent. of lead. A melt of bars, 999½ fine, weighing 931·53, was then made in a No. 40 black-lead pot. The king was added, mixed, and a sample cast; this sample assayed 996¼. It was fairly ductile, had a good lustre and color, but when compared with a strip of fine silver it was appreciably (though not greatly) darker in tint.

A coating of bone ash was put on and the nitreing performed as in the previous case. Samples were taken out and assayed from time to time until the metal was found to be sufficiently refined. In about one hour the bone ash was removed and the bars cast. Owing to some accidental cause (probably the want of a sufficient covering of charcoal), the metal "spurted" or "vegetated" on the surface, rendering it necessary to remelt and recast the bars, and when this was done they presented to the eye all the characteristics of perfectly pure metal. When the small chip was cut off for assay, there was no evidence of a tendency to crystallization, and the sample was laminated into a ribbon $\frac{1}{100}$th of an inch in thickness, without splitting. The assay showed that the metal was now refined to 999½ thousandths.

To briefly recapitulate, the results obtained in this work—which the writer desires shall be regarded rather as preliminary, and therefore capable of possible modification on more extended investigation—are these:

It was ascertained that the arsenical silver alloy, contrary to the general expectation, was the least volatilizing in silver in comparison with more refractory metals, and that the alloy might contain one per cent. of arsenic (silver 990, arsenic 10) without materially injuring the ductility; but if carried to two and a half per cent., the mixture was quite brittle.

The antimonic-silver alloy caused a very much greater loss of silver, and yet its brittling effect was much less than had been anticipated. Bismuth was the most brittling, and in this experiment proved by far the most difficult to remove by fluxes that operated effectively upon the two former.

Lead caused a greater loss than any of the former with the exception of antimony. The brittleness of those was crystalline, of this rather crumbly or amorphous, yet three parts in a thousand did not spoil the ductility.

While it has been a source of regret to the writer that these trials have been suspended, for the reason given, prior to the completion of the pre-arranged schedule, he is led to hope that they may form the entering wedge into future investigations, which are much needed to afford a complete elucidation of the difficulties that beset the manipulator in the precious metals, whether in the preparation of coin metal, ornamental ware or gold leaf, in the want of ductility of the alloys, and he is also encouraged to think that they may serve to throw a passing glimmer of light upon this rather obscure subject, in support of which hope he refers the reader to an extract on this subject from the letter of the assayer, already alluded to.*

TABLES.

The following tabular statement shows the gross weight of metal operated upon in each experiment and the amount of fine silver contained therein, together with the gross weight and amount of fine silver recovered from the toughening process:

FIRST EXPERIMENT.	OUNCES.	
	Gross Weight.	Fine Silver.
Refined silver, 999 fine, . . .	1052·46	
Metallic arsenic, . . .	2·52	
Total weight of metal operated on, .	1054·98	1051·40
Total weight of metal recovered in the form of bars, samples and "sweep," .	1053·32	1051·15
Apparent loss of silver, . .		·25
SECOND EXPERIMENT.		
Refined silver, 998 fine, . . .	905·68	
Metallic antimony, . . .	2·79	
Total weight of metal operated on, .	908·47	903·86
Total weight of metal recovered, . .	903·16	900·21
Apparent loss of silver, . . .		3·65

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* "I took a particular interest in this investigation for two reasons: First, I was sure that we knew too little practically about the effect of a small presence of such metals as arsenic, lead, etc. That is, we depended too much upon supposition, as to the extent or the degree in which they were injurious to the precious metals for coining purposes. It was worth while to make some severe and decisive tests upon that point. * * * As you have already seen by Mr. Outerbridge's report in detail, the alloying and volatilizing experiments were made with four metals in conjunction with silver, namely: arsenic, antimony, bismuth and lead. These are the chief enemies that trouble the camp of the silver miner and refiner. Nor are they less dreaded at the mint, since a small proportion of either will make our gold or silver refractory, brittle, crystalline or crumbly. * * * We must have ductile metal to work with. Hence these experiments have for us, as I have said, a twofold interest, as hitherto there have been no trials that we know of, at home or abroad, on any considerable scale, or in proper bulk. * * * On the whole we have learned a good deal, and I hope these experiments, without respect to the saving from waste, may be made accessible to parties interested in our own land and in foreign parts"

THIRD EXPERIMENT.

Refined silver, 998 fine,	1026·39	
Metallic bismuth,	2·96	
Total weight of metal operated on,	1029·35	1024·33
Total weight of metal recovered,	1027·18	1023·31
Apparent loss of silver,		1·02

FOURTH EXPERIMENT—(*Supplemental*).

Silver-bismuth alloy, 996¼ fine,	1020·56	1016·73
Total weight of metal recovered,	1015·79	1015·31
Apparent loss of silver,		1·42

FIFTH EXPERIMENT.

Refined silver, 999½ fine,	1014·36	
Metallic lead,	2·78	
Total weight of metal operated on,	1017·14	1013·85
Total weight of metal recovered,	1011·78	1010·78
Apparent loss of silver,		3·07

REMARKS ON THE GENERAL THEORY OF THE CENTRIFUGAL GOVERNOR FOR STEAM ENGINES.

By L. d'Auria,

Professor of Applied Mechanics; former Engineer of the Military Topographic Institute in Italy, Marine Architect, etc.

In any centrifugal governor, the masses moved by the centrifugal force resist the rotation by the inertia with a force equal to the masses multiplied by the acceleration. This force acting tangentially, it occasions a certain friction which resists the radial movement of said masses by the centrifugal force, which friction must be taken in consideration in the equation of dynamical equilibrium of the system.

If we indicate by ΣW, the sum of the weights moved by the centrifugal force in any centrifugal governor; by ρ, the variable distance of their common centre of gravity from the axis of rotation (the weights ΣW are supposed to have the same point of suspension); by

θ, the angle made by the axis of rotation with the straight line joining the centre of gravity of ΣW with the suspension; by N_1 and N respectively the numbers of revolutions per minute required by the governor to act when in its lower position calculated with and without the influence of the tangential force of inertia; by t, the time in which the governor passes from the speed of N to N_1 revolutions per min., which passage we suppose takes place with uniformly accelerated motion; the equation of dynamical equilibrium will be, according to the supposition,

$$\frac{\Sigma W}{900\text{ g.}} N_1^2 \pi^2 \rho \cos.\theta = \Sigma W \sin.\theta + f \frac{\Sigma W}{180\text{ g. } t}(N_1 - N)$$

in which the last term represents the tangential force of inertia multiplied by a coefficient f of friction, which reduced the friction to a resistant force applied at the centre of gravity of the weights ΣW.

Now from this equation we obtain

$$N_1 = \frac{5}{2}\frac{f}{t\pi\cos.\theta} + \sqrt{\frac{25}{4}\frac{f^2}{t^2\pi^2\cos.^2\theta} + \frac{900\text{ g. tang. }\theta}{\pi^2\rho} - \frac{5Nf}{t\pi\cos.\theta}}$$

and observing that

$$\frac{900\text{ g. tang. }\theta}{\pi^2\rho} = N^2$$

will be

$$N_1 = N;$$

which shows how harmless the tangential force of inertia is in centrifugal governors, and how useless are the devices proposed by some inventors for the elimination of the friction arising from it.

Molecular Vibrations in Magnetic Metals.—De la Rive showed, in 1846, that when a rapidly interrupted electric current traverses a stretched iron wire it produces sounds corresponding to the number of interruptions. M. Ader reports some late experiments which lead him to the following conclusions: 1. With all magnetic metals the passage of an undulatory current produces internal molecular vibrations which yield audible sounds. 2. In order to increase the intensity of the vibrations, some mechanical action should be opposed to the wires or bars, such as the inertia of two heavy masses at their extremities. The experiments are most successful with a battery which furnishes electricity in quantity and with a short circuit.—*Comptes Rendus.*

THE following table of elements was constructed from a similar one intended for

Nitrogen	N	14	III, v		Gas	Rutherford	1772	Sn
Osmium	Os	199.2	ii, IV		Solid	Tennant	1803	In
Oxygen	O	16	II	Di. and Triat.	Gas	Priestley	1774	Pb
Palladium	Pd	106.6	ii, IV		Solid	Wollaston	1803	Cd
Phosphorus	P	31	III, v,	Tetratomic	"	Brandt	1669	Tl
Platinum	Pt	197.4	ii, IV		"	Wood	1741	Co
Potassium	K	39.1	I,		"	Davy	1807	Ni
Rhodium	Ro	104.4	ii, IV		"	Wollaston	1803	Fe
Rubidium	Rb	85.4	I		"	Bunsen	1860	Zn
Ruthenium	Ru	104.4	ii, IV		"	Claus	1845	Mn
Selenium	Se	79.4	II, iv, vi,	Di. & Hexat.	"	Berzelius	1817	La
Silicon	Si	28	IV		"	"	1823	D
Silver	Ag	108	I,		"	Ancients		Ce
Sodium	Na	23	I,		"	Davy	1807	Th
Strontium	Sr	87 5	II,		"	"	1808	Zr
Sulphur	S	32	II, iv, vi,	Di. & Hexat.	"	Ancients		Al
Tantalum	Ta	182	V		"	Ekeberg	1802	E
Tellurium	Te	128	II, iv, vi		"	Klaproth	1798	Y
Thallium	Tl	204	I, iii		"	Crookes	1861	G
Thorium	Th	231	IV		"	Berzelius	1829	Mg
Tin	Sn	118	ii, IV		"	Ancients		Ca
Titanium	Ti	50	IV		"	Klaproth	1794	Sr
Tungsten	W	184	iv, VI		"	De Luyart		Ba
Uranium	U	240	ii, iv, $(U_2)^{VI}$		"	Peligot	1841	Li
Vanadium	V	51 3	iii, $(V_2)^{IV}$, V, $(V_2)^{VIII}$		"	Sefstroem	1830	Na
Yttrium	Y	6.7	II		"	Woehler		K
Zinc	Zn	65	II	Monatomic (?)	"	Paracelsus	15—	Rb
Zirconium	Zr	89.6	IV		"	Berzelius	1824	Cs

Cathode.

* Apparent Valences. † Elements not otherwise marked are presumed to have a diatomic molecule.

‡ At ordinary temperatures.

coke could not, of course, be used in the manufacture of Bessemer pig iron, and it is believed that in many cases unsatisfactory results have been obtained simply by the use of an impure fuel.

The following table of elements was constructed from a similar one intended for the instruction of the classes in the University of Pennsylvania in 1873, and will be found a useful table of reference for historical and statistical data.

Such a table, constructed with due care, can never represent the exact condition of chemistry at the time, for the reason that chemical investigation is always in advance of its general literature.

1879.

TABLE OF ELEMENTS.

Prepared for the course of Lectures at the Franklin Institute, on Introduction to Modern Chemistry, by Persifor Frazer, Jr., A. M.

Name.	Symbol.	Atom Wt.	*Ap. Val.	†Molecule.	‡State.	Discoverer.	Date.	Anode.
Aluminum	Al	27.4	IV, $(Al_2)^{VI}$		Solid	Woehler	1823	O
Antimony	Sb	122	III, v		"	Valentine	14—	S
Arsenic	As	75	III, v,	Tetratomic	"	Schroeder	1694	N
Barium	Ba	137	II,	Monatomic, (?)	"	Davy	1808	F
Bismuth	Bi	210	III		"	Agricola	1529	Cl
Boron	B	11	III		"	Davy	1807	Br
Bromine	Br	80	I, iii, v, vii		Liquid	Balard	1826	I
Cadmium	Cd	112	II,	Monatomic	Solid	Stromeyer	1817	Se
Caesium	Cs	133	I		"	Bunsen	1860	P
Calcium	Ca	40	II		"	Davy	1808	
Carbon	C	12	ii, IV		"	Ancients		As
Cerium	Ce	92	II		"	Berz. and Hisinger	1803	Cr
Chlorine	Cl	35 5	I, iii, v, vii		Gas	Scheele	1774	V
Chromium	Cr	52.4	II, iv, $(Cr_2)^{VI}$		Solid	Vauquelin	1797	Mo
Cobalt	Co	59	II, iv, $(Co_2)^{VI}$		"	Brandt	1733	W
Copper	Cu	63.4	II $(Cu_2)^{II}$		"	Ancients		B
Didymium	D	96	II		"	Mosander	1841	C
Erbium	E	113 7	II		"	Mosander	1843	Sb
Fluorine	F	19	I		Gas	Knox (?)	1836	Te
Gallium	Ga	70(?)			Solid	Boisbaudran	1875	Ta
Glucinum Be. or	G	9.4	II		"	Woehler	1828	Cb
Gold	Au	197	III		"	Ancients		Ti
Hydrogen	H	1	I		Gas	Cavendish	1766	Si
Indium	In	113.7	III		Solid	Reich and Richter	1863	H
Iodine	I	127	I, iii, v, vii		"	Courtois	1812	Au
Iridium	Ir	198	ii, IV		"	Tennant	1804	Os
Iron	Fe	56	II, iv, $(Fe_2)^{VI}$		"	Ancients		Ir
Lanthanum	La	92.5	II		"	Mosander	1839	Pt
Lead	Pb	207	ii, IV		"	Ancients		Ro
Lithium	Li	7	I		"	Davy	1818	Ru
Magnesium	Mg	24	II		"	"	1808	Pd.
Manganese	Mn	55	II, iv, $(Mn_2)^{VI}$		"	Gahn	1774	Hg
Mercury	Hg	200	II, $(Hg_2)^{II}$	Monat.	Liquid	Ancients		Ag
Molybdenum	Mo	95.8	ii, iv. VI		Solid	Hjelm	1782	Cu
Nickel	Ni	59	II, iv, $(Ni_2)^{VI}$		"	Cronstedt	1751	U
Niobium	Nb	94	V		"	Hatchett	1801	Bi
Nitrogen	N	14	III, v		Gas	Rutherford	1772	Sn
Osmium	Os	199.2	ii, IV		Solid	Tennant	1803	In
Oxygen	O	16	II	Di. and Triat.	Gas	Priestley	1774	Pb
Palladium	Pd	106.6	ii, IV		Solid	Wollaston	1803	Cd
Phosphorus	P	31	III, v,	Tetratomic	"	Brandt	1669	Tl
Platinum	Pt	197.4	ii, IV		"	Wood	1741	Co
Potassium	K	39.1	I,		"	Davy	1807	Ni
Rhodium	Ro	104.4	ii, IV		"	Wollaston	1803	Fe
Rubidium	Rb	85.4	I		"	Bunsen	1860	Zn
Ruthenium	Ru	104.4	ii, IV		"	Claus	1845	Mn
Selenium	Se	79.4	II, iv, vi,	Di. & Hexat.	"	Berzelius	1817	La
Silicon	Si	28	IV		"	"	1823	D
Silver	Ag	108	I,		"	Ancients		Ce
Sodium	Na	23	I,		"	Davy	1807	Th
Strontium	Sr	87 5	II,		"	"	1808	Zr
Sulphur	S	32	II, iv, vi,	Di. & Hexat.	"	Ancients		Al
Tantalum	Ta	182	V		"	Ekeberg	1802	E
Tellurium	Te	128	II, iv, vi		"	Klaproth	1798	Y
Thallium	Tl	204	I, iii		"	Crookes	1861	G
Thorium	Th	231	IV		"	Berzelius	1829	Mg
Tin	Sn	118	ii, IV		"	Ancients		Ca
Titanium	Ti	50	IV		"	Klaproth	1794	Sr
Tungsten	W	184	iv, VI		"	De Luyart		Ba
Uranium	U	240	ii, iv, $(U_2)^{VI}$		"	Peligot	1841	Li
Vanadium	V	51 3	iii, $(V_2)^{IV}$, V, $(V_2)^{VIII}$		"	Sefstroem	1830	Na
Yttrium	Y	6.7	II		"	Woehler		K
Zinc	Zn	65	II	Monatomic (?)	"	Paracelsus	15—	Rb
Zirconium	Zr	89.6	IV		"	Berzelius	1824	Cs

Cathode.

* Apparent Valences. † Elements not otherwise marked are presumed to have a diatomic molecule.

‡ At ordinary temperatures

PHOSPHORUS IN COAL.

By Andrew S. McCreath, Harrisburg, Pa.

Read at the Pittsburgh Meeting of the American Institute of Mining Engineers, May 13th, 1879.

The manufacture of pig iron for conversion into steel by the Bessemer and open-hearth processes, is now one of the most important industries of the United States. It is necessary that iron intended for this purpose should be very pure, and especially must it be comparatively free from phosphorus. Great care must therefore be exercised in the selection of proper ores, flux, and fuel. Only such ores as are practically free from phosphorus can be used, and pure fuel is as much a necessity as pure ores; though hitherto iron men have paid comparatively little attention to this point.

During the course of my work as chemist for the Second Geological Survey of Pennsylvania, I had occasion to examine some of the bituminous coals of the State for phosphorus, and the results obtained are so interesting that I venture to present them to the notice of the members of the Institute.

The coals are arranged in geological order according to the different beds, and the table shows the percentage of phosphorus in the coal and also in the coke.

The greatest number of specimens have been selected from the Pittsburgh bed, because it is the principal coal-bed of South-western Pennsylvania, and most of the mineral fuel which is mined along the Youghiogheny and Monongahela rivers, to be used in the coke ovens of the Connellsville region and in the blast furnaces and mills of Pittsburgh and its vicinity, and to be shipped to Western and Southern markets, comes from this bed.

It will be noticed that many of the specimens examined contain phosphorus in most objectionable quantities. In the twenty-four coals tested from this bed, the amount of phosphorus varies from a mere trace to ·1248 per cent., equal to ·2003 per cent. in the coke. Such a coke could not, of course, be used in the manufacture of Bessemer pig iron, and it is believed that in many cases unsatisfactory results have been obtained simply by the use of an impure fuel.

Table showing the Percentage of Phosphorus in Certain Coals.

	Name of Coal.	County.	[Coal bed.	Phos. per ct. in *coal.*	Phos. pet ct. in *coke.*
1	Henderson's, Buffalo Township	Washington.	Washington.	·1667	·2818
2	Lucas's, Dunkard Township	Greene.	Sewickley.	·0053	·0084
3	Miller's, Dunkard Township	"	Pittsburgh.	·0025	·0041
4	Magee's, Independence	Washington.	"	·0254	·0438
5	Ashurst's, Chartiers	"	"	·0491	·0846
6	Red's, Fallowfield	"	"	·0943	·1551
7	New Eagle Works, Carroll Township	"	"	·0013	·0020
8	White's, East Pike Run Township	"	"	·1248	·2003
9	Slocum's, East Pike Run Township	"	"	·0011	·0018
10	Penn Gas Coal Co.'s Youghiogheny Shaft	Westmoreland.	"	·0058	·0095
11	Penn Gas Coal Co.'s Penn Shaft	"	"	trace.	trace.
12	Penn Gas Coal Co.'s Sewickley Shaft	"	"	trace.	trace.
13	Westmoreland Coal Co.'s Southside Mine	"	"	·0092	·0150
14	Westmoreland Coal Co.'s Larimer Mine	"	"	trace.	trace.
15	Westmoreland Coal Co.'s Foster Mine	"	"	·0402	·0652
16	Millwood Coal Co.'s, Derry Township	"	"	·0801	·1177
17	Saltzburg Coal Co.'s, Loyalhanna Township	"	"	·0307	·0452
18	Saxman & Co.'s, Derry Township	"	"	·0167	·0247
19	Greensburg Coal Co.'s, Hempfield Township	"	"	·0070	·0107
20	Frick & Co.'s, Connellsville Township	Fayette.	"	·0111	·0161
21	Townsend's, Perry Township	"	"	·0022	·0034
22	McCormack Heirs, Franklin Township	"	"	trace.	trace.
23	Swan Heirs, North Union Township	"	"	trace.	trace.
24	Kendal's, German Township	"	"	·0020	·0031
25	Saylor Hill, Summit Township	Somerset.	"	·0058	·0074
26	Wilhelm Mine, Elk Lick Township	"	"	·0122	·0156
27	Coleman Brothers, Valley Township	"	Berlin.	·0105	·0135
28	Cotter's, Raccoon Township	Beaver.	Bed E.	·0058	·0094
29	Dysart & Co.'s, Washington Township	Cambria.	"	·0530	·0688
30	Dennison, Porter & Co.'s, Allegheny Township	Blair.	"	·0075	·0103
31	Diehl's, Green Township	Beaver.	Bed D.	trace.	trace.
32	R. J. Hughes & Co.'s, Decatur Township	Clearfield.	"	·0080	·0107
33	Rockhill Iron and Coal Co.'s, Carbon Township	Huntingdon.	"	trace.	trace.
34	Joseph Ramsey, Jr.'s White Township	Cambria.	Bed C.	·0078	·0105
35	Dennison, Porter & Co.'s, Allegheny Township	Blair.	Bed B.	·0053	·0072
36	Cambria Iron Co.'s, Allegheny Township	"	"	trace.	trace.
37	Cambria Iron Co.'s, Conemaugh Township	Cambria.	"	trace.	trace.
38	Dysart & Co.'s, Washington Township	"	"	trace.	trace.
39	Brotherline's, Clearfield Township	"	"	trace.	trace.
40	Savage Colliery, Todd Township	Huntingdon.	....	·0080	·0098

Substitution of Steel for Iron.—The first iron vessel was built in 1820, for the trade between London and France. Thirty years afterwards the tonnage of the iron steamers was only one-fourth as great as that of the wooden steamers. In 1860 nearly four-fifths of the English steamer tonnage was iron; in 1868 nearly ten-elevenths of the tonnage was iron. Prior to 1870 only 27,000 tons of steel had been used in ship building; since that time the price of steel has steadily approximated to that of iron, and the production of steel has increased twentyfold. The leading railroads are gradually replacing their iron rails by steel, which cost but little more and last three times as long. A similar substitution is gradually taking place in the ship yards.—*Fortsch. der Zeit.*

NOTE ON THE DETERMINATION OF SILICON IN PIG IRON AND STEEL.

By Dr. Thomas M. Drown, Lafayette College, Easton, Pa.

(Read at the Baltimore meeting of the American Institute of Mining Engineers, February, 1879.)

In experimenting in connection with Mr. P. W. Shimer (now chemist of the Thomas Iron Company, Hokendauqua, Pa.), on methods for the determination of silicon in pig iron, in order to find one which should be accurate and yet give results in a few hours, I have adopted the following procedure, which, as far as my experience goes, leaves nothing to be desired.

About one gramme of pig iron or steel is treated in a platinum or porcelain dish with 25 cubic centimetres of nitric acid (sp. gr. 1, 2). When action has ceased, 25 to 30 cubic centimetres of dilute sulphuric acid (one of acid and three of water) are added, and heat applied until the nitric acid is nearly or quite driven off. The heat of a water-bath is sufficient, though the process may be hastened by heating higher on a sand-bath. Water is then cautiously added (as soon as the free sulphuric acid is sufficiently cool) and the contents of the dish heated until the crystals of ferric sulphate are completely dissolved. The solution is then filtered *as hot* as possible, the residue washed first with hot water, then with 25 to 30 cubic centimetres of hydrochloric acid (sp. gr. 1, 12), and finally with hot water. After drying and igniting, the silica will be found to be snow-white and granular.

The following are some results obtained by this method compared (in some instances) with the older method of treatment with nitric acid, evaporation to dryness, heating to 150°C. for several hours, dissolving out the iron in hydrochloric acid, and filtering off from the insoluble residue, which is dried and ignited, and the resulting impure silica fused with alkaline carbonates.

The letters denote different samples of pig iron.

	Per Cent. of Silicon.							
	A	B	C	D	E	F	G	Bessemer steel.
Old method,	2·64	2·46		1·45	1·65			·672
New method, 1	2·70	2·47	1·13	1·63	1·53†	1·66	2·50	·676
" " 2	2·68	2·47	1·18	1·62	1·51†	1·68	2·50	·672
" " 3	2·81*	2·47		1·65	1·51†	1·72	2·50	·672
" " 4					1·63‡	1·70	2·47	
" " 5					1·65‡		2·46	
" " 6					1·65‡			

Some incidental results obtained in developing this process have enough interest to be worthy of record. Treatment of pig iron with concentrated sulphuric acid, heating till fumes arise, diluting with water, and filtering after all action has ceased, gives a silica which is seldom pure, and yet the results are considerably too low.

Treatment with dilute sulphuric acid and evaporation till the acid fumes in the air, then filtering after dilution, gives occasionally results which are accurate; but this method is uncertain, depending on the fineness of the borings and character and composition of the pig iron. The silica obtained is seldom white. The following are some results obtained in this way:

	Per Cent. of Silicon.			
	A	B	C	D
Old method . . .	1·02	1·64	2·64	3·85
New method, 1 . .	1·05	1·73	3·00	3·88
" " 2 . .	1·05	1·69	2·98	3·91
" " 3 . .	1·05	1·70	2·97	
" " 4 . .			3·01	

---

* Not washed with hydrochloric acid.

† In these analyses hydrochloric acid was used after the addition of nitric acid, and was not completely driven off.

‡ Hydrochloric acid was used for solution instead of nitric acid.

Treatment in platinum dishes gave very slightly lower results than porcelain dishes.

If after treatment with dilute sulphuric acid the solution is filtered off from the residue without concentration of the acid, it is found that about one-half of the silicon is in the solution and the other half in the residue; when nitric acid is used and the solution filtered off as soon as all action has ceased, it is found that about two-thirds of the silicon is in the solution and one-third in the residue; and with hydrochloric acid, about one-third goes into solution and two-thirds remains in the residue. It is not probable that there is any precise ratio existing between the amount of silicon dissolved and the amount in the residue in the case of any one of the acids, the ratio being doubtless variable and depending on the concentration of the acid, the time of action, and the temperature; yet the marked difference in the action of the three acids in this respect is interesting.

The washing with hydrochloric acid of the residue obtained by the action of nitric and sulphuric acids on pig iron is in most cases necessary. Thus there was obtained from a pig iron when water only was used for washing, 2·67 per cent. of silicon against 2·52 when washed with hydrochloric acid; and in another sample, 2.10 per cent. against 1·70 per cent.

Although the results obtained with hydrochloric acid for the original solution of the iron show, as far as the experiments go, as good results as those obtained with nitric acid, yet I prefer the nitric acid treatment on account of the silica obtained, being compact and granular, while the use of hydrochloric acid, and also of sulphuric acid alone, yields a silica which is light and flaky.

Lactic Fermentation.—Richet has studied the effects of oxygen, of boiling, and of digestives, upon lactic fermentation. He finds that the fermentation in an elongated tube is only from 65 to 70 per cent. as great as in an ordinary flask. Below 44° (111·2° Fahr.) the activity of fermentation increases with the temperature. From 44° to 52° (125·6° Fahr.) there is no change; above 52° the activity diminishes in proportion as the temperature increases. He attributes the resistance of boiled milk to fermentation to the coagulation of an albuminoid substance which contributes to the development of the ferment.—*Comptes Rendus.* C.

REPORT OF THE COMMITTEE ON SCIENCE AND THE ARTS ON THE HITCHCOCK LAMP.

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 2, 1879.

The Sub-committee of the Committee on Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination the Hitchcock Lamp, report that the apparatus is a mechanical (or blast) lamp of improved construction, which, in the form submitted for examination, is especially adapted for consuming fat or greasy oils, animal or vegetable, and without the aid of a chimney, the oil being supplied to the wick by the same mechanism that supplies the blast. Leaving out of consideration for the present the general features of mechanical excellence of construction which characterize the lamp, and which, by giving it superior strength and accuracy of working, add to its utility and durability, your committee find that the special novelty in its construction lies in the functions which the mechanism is called upon to perform—that is to say, to furnish a forced blast or draft to the flame and at the same time to deliver the oil to the wick, both of which operations are performed simultaneously and continuously so long as the mechanism is working. This feature will appear more distinctly by instituting a comparison between the Hitchcock lamp and other mechanical lamps with which your committee is familiar.

The Carcel lamp is designed to burn fat oils. The air supply to the flame is obtained by the use of a chimney of about 11 inches in height, while the oil is supplied to the flame by a mechanical movement.

The Jones & Hitchcock lamp—the immediate predecessor of the lamp before the committee—is designed to burn kerosene without a chimney, the necessary air supply being obtained by mechanical means.

In the Carcel lamp, with a chimney, the movement supplies the oil to the flame. In the Jones & Hitchcock lamp, without a chimney, the movement furnishes the air supply to the flame. In the Hitchcock lamp before the committee the movement combines both these functions, supplying the blast and feeding the oil simultaneously.

As compared with either the Carcel or the Jones & Hitchcock lamp, the movement is more compact and considerably more effective, possessing the capacity of furnishing a continuous light for 12 hours, while that of the Carcel and Jones & Hitchcock are limited respectively to 6 and 7 hours.

Referring to the mechanical details and workmanship displayed in the Hitchcock lamp, your committee find it in these particulars worthy of unqualified praise, and, of the two samples before the committee, one has been kept in almost continuous experimental service for over a year and the other about half that time, and with very satisfactory results.

The lamp can readily be taken apart for cleaning and repairs, the principle elements—*i. e.* the movement, the pump and the wick tube—being readily removable from the shell or body, and as easily returned.

The elliptical form of the wick tube, in the opinion of your committee, has several advantages over both the flat and the cylindrical wick, as the flat form gives no interior current of air, and would be quite inapplicable to this form of lamp by making the combustion imperfect; and the circular wick, though avoiding this objection, does not utilize the interior air current as effectively as the elliptical or compressed form, which gives practically the same results as regards luminosity as two flat flames.

The committee have been aided in getting at the illuminating value of the lamp by the courtesy of Dr. Cresson, whose comparative photometric measurements and results are given herewith on his authority:

Results of Experimental Trials with the "Hitchcock Blast Lamp" from the Hitchcock Lamp Company. (No Chimney.)

PHILADELPHIA, July 18, 1876,
417 Walnut Street.

Car Lamp with LARD OIL:

Specific gravity of oil,	0·911
Or 1 U. S. gallon weighed	7·59 pounds.

Continuous trial of 12 hours' duration.
Hourly observations upon consumption of oil.
Half-hourly observations upon candle power.

Average consumption of oil per hour,	922·4 grains.
Average light produced,	16·9 candles.
Average consumption of oil per candle light,	54·5 grains.

Or 1 gallon of oil will give 16·9 candle light for 57 hours.

When solid lard was used:

Hourly consumption of lard,	882· grains.
Light produced,	14·85 candles.

Average consumption of lard per candle light,	59·4 grains.
One pound of lard gives light of . .	117·8 candles.

Trials with Thackara & Buck's best Lard-oil Burner, with glass chimney 8 inches high, gave:

Average consumption of oil per hour, . .	805· grains.
Average light, ...	13·4 candles.
Grains of oil per candle light, . .	60·5

The best and most economical results were obtained from the Hitchcock lamp when it was giving a light equal to that from 17 candles. When it was burned at the rate of 15 candles the consumption of oil per candle light rose to 57 grains, and when at 21 candle lights to 70 grains per candle light.

The ordinary solar lamp could not be made to yield over 16 candles, and burned best at 13·5 candles, and at all times was very sensitive to cross-drafts and motion of the lamp.

The Hitchcock lamp gave decidedly the most satisfactory results, with the great advantage of the absence of a glass chimney, behaving well when placed in a strong draft of air, or when carried from place to place.

Car candles used for comparison burned at 209 grains per hour, and gave a light of 2·2 standard spermaceti candles, consuming 120 grains of sperm per hour. The above results are given in standard candle lights.

To this favorable opinion of Dr. Cresson, which your committee fully endorse, it should be added that the body of the lamp never becomes too hot for comfortable handling, even after burning for 12 hours, the maximum temperature being attained in about 5 or 6 hours.

The lamp is portable, and, your committee is advised, is made in a variety of styles and shapes to suit special services. The style before the committee is that employed in railway cars. The flame is very tenacious and the light very steady, requiring but little attention when the wick is properly trimmed and adjusted.

Your committee are of the opinion that the lamp combines the features of excellence, of mechanical construction and utility. Detailed drawings of lamp accompany this report—all of which is respectfully submitted.

WILLIAM H. WAHL, *Chairman.*
L. L. CHENEY,
ALBERT G. BUZBY.

Amended and adopted, May 7, 1879.
H. CARTWRIGHT,
Chairman pro tem.

ABSTRACT OF A REPORT OF EXPERIMENTS ON THE EFFICIENCY OF COKE GAS-GENERATORS WITH VARYING DRAFT.

Conducted under the auspices of the Verein von Gas- und Wasserfachmännern of Germany, by a committee consisting of E. Grahn, Simon Schiele, Dr. Schilling, and published in the Journal of the Society.

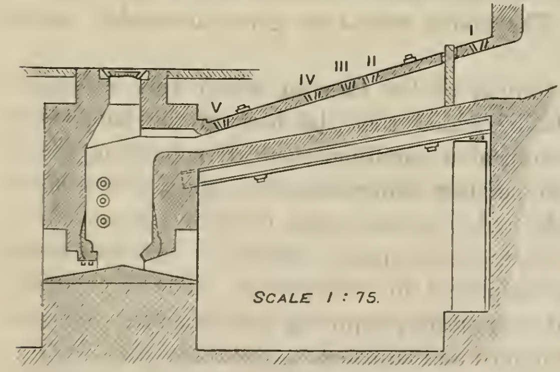
Translated by PHILIP PISTOR.

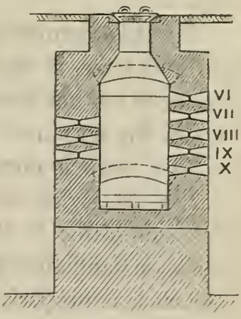
The experiments were conducted on the plan proposed by Dr. Bunte and adopted by the Society.

Carbonic oxide is most advantageously generated when it occurs continuously in unvarying quantities with the smallest possible percentage of carbonic acid and in such a manner that the operation is not disturbed by the removal of the slag or scoriæ deposited.

Experiments were conducted with a view to determine:

1. The quantity of gas generated in a given time.
2. The mean composition of the gas.
3. The formation and removal of the slag.





The experimental generator had at first no grate (one was introduced later during the experiments), but two slits or openings at the bottom, opposite each other, for the admission of air. It had 1 sq. metre cross section. From the upper edge of slit to lower edge of flue 1·5 m. The flue was of 0·25 sq. m. sectional area. Peep-holes were introduced in the sides every 0·25 m. of the height. The generator was charged from a hole in the top, which was closed with a flat luted cover. The draft was regulated by a damper in the flue. As a chimney of 36 m. height was available for the experiments, and it was desirable to obtain the full natural draft, the gases were conducted through a combustion chamber, to avoid danger of explosion in the chimney, to the same.

The draft pressure was determined by two manometers, one an ordinary water manometer for rough approximate measurements, the other a very sensitive one for precise measurements. Besides, an automatic self-registering Crosley manometer was used. They were connected by tubes with the flue. Experiments showed that it made no difference which way the openings of these tubes were directed with reference to the direction of the draft.

An aspirator exhausted small quantities of the gas at different times during each experiment, for analyzing purposes, and specimens were also taken from the peep-holes.

The following observations were recorded during each experiment:

1. Mean draft in flue.
2. Duration of experiment.
3. Weight of material charged.
4. Weight of ashes, clinkers, scoriæ.
5. Chemical composition of the gas.
6. Temperature in the flue.

Subtracting the weight of water and refuse from the mass charged, will give the weight of gasified particles*, which for coke may be taken without any great error as consisting of carbon. With this assumption, the volume of gas generated at 0° and 760 mm. pressure may be calculated as follows:

1 cub. m. carbonic acid and 1 cub. m. carbonic oxide contain exactly the same weight of carbon, viz., 0·5363 kilogrammes. The volume of the gases containing carbon in one cub. m. of gas generated will be given by the chemical analysis. Multiply this number by 0·5363 and we have the weight of carbon in 1 cub. m. of gas generated. Finally, this weight into the total weight of carbon consumed will give the total volume of gas generated.

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* The correction for weight of water was not taken into account, as it was found to vary as much for one and the same as for different kinds of coke.

Results of experiments with coke from Saar coal (Heinitz mines).

No. of Experiment.	Consumption of coke per 24 hours in kilog.	Refuse residue of coke in kilog.	Percentage of refuse, etc.	Actual consumption in kilog.	Gas generated contained a percentage of			Computed volume of gas per 24 h. reduced to 0° and 760 mm. barom. pressure.	Temperatures measured with Siemens' copper pyrometer or with the Siemens' electrical pyrometer.			Average draft pressure in mm. water.
									In flue.		In generator.	
					CO_2	CO	Total.		*a.*	*b.*		
								cub. m.				
1	785	111	14·1	674	2·	28·3	30·3	4110	500	550	725 to 750	+0·74
2	800	113	14·1	687	1·5	29·2	30·7	4189	400 to 500	550 to 575	750 to 800	+0·43
3	1200	151	12·6	1049	1·8	28·6	30·4	6396				—0·65
4	1330	167	12·6	1163	2·5	27·3	29·8	7091	550		800	—1·64
5	1650	188	11·4	1462	3·	26·9	29·9	9137	700 to 750	800 to 850		—2·8
6	1800	226	12·6	1574	3·3	26·9	30·2	9837	1130°			—3·7
7	1980	268	13·5	1712	3·5	26·2	29·7	10700	714		748	—4·1
8	2530	329	13·	2201	5·6	22·9	28·5	14386	800 to 900			—6·7
9	3226	409	12·7	2817	7·	23·3	30·3	17335	832			—14·

The draft gradually increased from ·45 mm. to 14 mm. pressure.

Experiments 1, 2, 3, 4 were conducted with a low draft, the upper layer of coke only attaining a cherry-red heat. Analysis showed an absence of oxygen. No difficulty was found in removing the slag—it flowed down through the opening and chilled.

Taking the first four experiments, we get an average of 0·164 kilog. carbon to the cub. metre.

Experiments 5, 6, 7 give 0·16 kilog. per cub. metre. During these experiments the damper was wider open, the draft considerably stronger ane the generator itself quite warm.

Experiment 8 gives 0·153 kilog. carbon per cub. metre. During this experiment a pan of water was placed before the slit, considerably reducing the heat radiated, and more thoroughly chilling the slag.

Experiment 9 gives 0·1625 kilog. carbon per cub. metre; no water used, but full available draft. The generator was intensely hot, the coke itself at a white heat.

The temperatures *a* and *b* in flue are taken at about 2 metres from each other.

Results of a series of experiments with coke from Bohemian coal from the Lititz colliery, near Pilsen.

No. of Experiment.	Consumption of coke per 24 h. in kilog.	Refuse residue, etc. of coke in kilog.	Percentage of refuse, etc.	Actual consumption in kilog.	Gas generated contained a percentage of			Comp. vol. per 24 h. reduced to 0° and 760 mm. barom. pressure in cub. m.	1 cub. metre contains carbon in kilog.	Temperature measured by a pyrometer. In flue.		Average draft pressure in mm. water.
					CO_2	CO	Total.			*a.*	*b.*	
A	904	163	18·9	741	1·4	29·4	30·8	4486	·165	430 to 480	600 to 625	+0·86
J	1338	351	26·2	987	3·6	25·0	28·6	6435	·153			—4·6
Z	1400	353	25·3	1047	2·3	24·4	26·7	7322	·143		950°	—2·1
D	1462	362	24·8	1100	1·8	28·2	30·	6837	·161	750		—0·55
H	1516	391	25·7	1125	7·4	20·7	28·1	7465	·151	850	950	—5·2
N	1610	274	17·	1336						730		—3·1
F	1690	312	18·5	1378	7·2	20·3	27·5	9210	·150	770		—6·0
G	1815	400	22·	1415	8·3	16·7	25·	10554	·134			—7·4
B	1770	280	15·8	1490	3·6	23·2	26·8	10365	·144			—4·5
K	1920	384	20·	1536	5·6	23·4	29·	9876	·155			—8 2
M	2107	421	20·	1686	5·2	23·6	28 8	10916	·154	880		—7·2
P	2160	367	17·	1793								—6·2
O	2190	372	17·	1818								—6·7
C	2714	271	16·9	2443	6·3	21·1	27 4	21590	·113	800	950 to 975	—5·24
E	3707	487	13·14	3220	12·5					850		-11·8

The draft was gradually increased, being regulated by the damper, from Experiments A to E, that is, from 0·86 mm. to 11·8 mm. pressure. As can be readily seen, the consumption of coal grows with it.

Experiments G, H, J, K were conducted with the original generator.

Experiments A, B were conducted with a mixture of the two kinds of coke.

It was then found necessary to take out the fire-brick lining at the bottom of the generator opening, and for bricks tapering inward to substitute such tapering outward, on account of the formation of slag, which choked the opening.

Experiment F was conducted with the modified generator and mixed coke, half of each.

Experiments L, M with ·9 of the latter kind, ·1 of the former.

Experiments C, D, E with mixed coke and introduction of steam.

Experiments N, O, P with a grate introduced in the generator and steam; Bohemian coke.

The slightest leak in the generator or flue showed an immediate increase of carbonic acid. In the duct or flue, as the tables show, the temperature fell from 100 to 150° from *a* to *b*, a distance of about 2 metres. This indicates a very rapid cooling of the gases, and shows the advisability of the shortest practicable duct to the combustion chamber.

A very remarkable result is that when the steam or vapor of water was used, notwithstanding the chilling of the air supplied for carbonization, the temperature of the gases was hardly any lower than when steam was not used. It would seem that the heat, partly radiated from generator and flue and partly utilized in melting the slag, was sufficient to decompose the water and produce a gas richer in hydrogen.

The high temperature of the carbonized gases causes an increased deposit of tar in the standpipes and hydraulic mains of gas works, and consequently when first introduced must be closely watched.

Pyrometric measurements of the air which was heated by being led around the side of the oven before being introduced into the combustion chamber show a temperature of 475°C. in this duct. As regards the formation of slag, the mixture of the two kinds of coke gave by far the best results.

As yet these generators have only been introduced in one large gas works in this country (United States), viz., the People's Gas Works, of Baltimore, Md., by their Chief Engineer, Mr. Dietrich. A short description of them was given at the meeting of the Society of Gas Lighting, Dec. 12th, 1878, and will be found in the *American Journal of Gas Lighting* of Jan. 16th, 1879.

The above experiments show widely varying results, depending principally on the quality of coke used, and consequently should be repeated with our own coals.

As a very considerable saving in fuel is claimed for this method of firing, as it considerably reduces the expense and increases the uniformity of firing, it would seem to be to the interest of some of the larger establishments to conduct a similar series of experiments, which would give reliable data for coke from American coals.

THEORY OF THE TELEPHONE.

The telephone, which was so easily explained in the beginning, is enveloped in difficulties, and requires to be studied attentively. The iron plate vibrating under the influence of the voice in the transmitter, and subject to the action of the magnet in the receiver, was regarded as indispensable. We know now that it is possible to replace it in the receiver by non-magnetic substances, by a plate of copper, of glass, of wood, and even of card-board. It was believed then that the magnet exercises a particular action upon the bodies.

We have been mistaken, not in the fact, but in its cause, and if the glass, the wood, and other substances not magnetic transmit the sound, it is because the wood which surrounds and contains the magnet receives the molecular vibrations which are there produced, and communicates them to the substances which are applied to them.

To prove this fact, I availed myself of a microphone as a transmitter, and of a metronome, of which the strokes were regular and uniform and liable to little deviation, while you could study the conditions which gave more or less intensity in the receiving telephone.

It was possible to separate the mouth-piece of the telephone and the diaphragm of iron, and replace it by a glass plate. If you then applied the ear, after having well appreciated the intensity of the strokes which were heard, and raised it little by little to one side only, keeping the other side of the telephone supported, so that the distance could be measured, the intensity underneath diminished hardly any, and when it was placed at a right angle to the side of the instrument, the strokes had nearly the same force; but when you separated the wood a little, the sound stopped, and it was necessary to conclude that the case of the telephone even transmitted vibrations, for as soon as the edge of the glass came to be touched the strokes of the metronome were heard.

You hear equally well by applying the ear to the extremity of a thin glass plate of twenty-five centimetres, the other end of which rested on the side of the telephone. The same experiments have been made with plates of copper, of wood, and of card-board, the differences in the intensity of the sounds noticed being only due to the greater or less facility with which bodies of different natures receive and transmit vibrations. With a plate of iron, the strokes transmitted are much stronger, and have a particular sound which diminishes rapidly in proportion as you raise the plate; and it is easy to understand that it is the influence of the magnet which is thus enfeebled, while the effect of the molecular vibrations of the case keeps up and causes it to be heard, as in the case of plates which were not magnetic.

It must be inferred, then, that in a telephone receiver the iron diaphragm is subjected to a double influence: that of the magnet and the case in which in which it is fixed, and as a practical consequence it is shown that in the construction of a telephone the choice of the case and the manner in which the magnet is fixed are not indifferent matters.

These facts confirm the opinion of Du Moncel, who attributes the effects of the telephone to molecular vibrations of the magnet, and the iron diaphragm only strengthens the vibrations and renders them more sensible to the ear in vibrating itself. The same causes act also in the transmitting telephone, but in an inverse sense; that is to say, the molecular vibrations excited in the case are transmitted to the magnet, and produce in the magnetism of the bar modifications which are transferred by induction currents to the coil. We may say, also, that the vibrations of the case are transmitted directly to the coil in the presence of a magnet producing the induction currents. This manner of regarding it will conform more to what is known of the origin of indirect currents.

Whatever conclusions may be drawn from the facts, the following can be used in the argument: By raising the mouth-piece, and the iron diaphragm of the telephone, and holding it firmly in the one hand, and with the other drawing a violin bow lightly upon the edge, you obtain a sharp sound that can be heard clearly in the receiving telephone. A small ruler placed crosswise before the instrument, and passing beyond it some centimeters, produces a sound when struck at the end with the bow, so that when it is shortened the sounds are elevated and gave those of an ascending gamut, which immediately came to the ear at the receiver. What is surprising in this experiment is that the grave notes, which shake the instrument and the hand, are not heard in the receiver, while the sharp notes are reproduced there easily, and the reason perhaps is because the vibrations from the sharp sounds approach to the character of molecular vibrations. It is perhaps needless to say that with an iron diaphragm these facts assume an entirely different character. It has already been demonstrated that the strokes made on the magnet, the coil or the case were heard in the receiver. The molecular shock which sufficed for the telephone receiver is too feeble to cause the transmitter to speak. Besides it may be said that the iron diaghragm, vibrating by speech, exercises a double influence, and that to the magnetic effects in the bar may be added the vibrations which it directly transmits to the case.

The effects from the telephone are too usually attributed to the sensible vibrations of the iron plate moving backward and forward from the magnet, representing the well known and habitually accepted action; but the molecular vibrations which are performed, so to speak, atom by atom in the immovable plate, play a more important part, and without them articulated speech would be impossible.

The telephone and, above all, the microphone prove to us by surprising phenomena just how far the division and reciprocity of forces may go. But what is still more admirable than these new and marvelous instruments is the old and incomparable delicacy of the ear, which perceives and appreciates, without allowing to escape from it a single one of the thousands of movements which loose themselves in some manner in the infinitely little.—*Les Mondes.*

CARBURETTING AIR.

The cost required to produce the electric light is not easily obtained, but enough is known at present to condemn it as too expensive for commercial use; but the cost of carburetted air or gas is indisputably confirmed by practical experiment.

Practical Test.—Barometer 29·8, temperature 56°; the weight of gasoline, 655 grains to water, 1000 grains; therefore, one gallon of gasoline = 45,850 grains. The air was simply aspirated at the rate of 6 cubic feet per hour through an ordinary chemist's wash bottle, and each cubic foot took up 735 grains illuminating gas of 17·10 candles, taking 585 grains.

Grains.

$$\frac{\text{1000 cubic feeet of air} = 735{,}000}{\text{1 gallon of gasoline} = 48{,}850} = 16{\cdot}0 \text{ gallons of gasoline per 1000 cubic feet of air.}$$

$$\frac{\text{1000 cub. ft., 17·10 gas,} = 585{,}000}{\text{1 gallon of gasoline} = 45{,}850} = 12{\cdot}7 \text{ gallons of gasoline per 1000 cubic feet of gas.}$$

1000 cubic feet of air, after being carburetted, = 1320 cubic feet, and 1000 cubic feet of 17·10 gas, after being carburretted, = 1270 cubic feet.

Specific-Gravity Test.—The time required to pass equal volumes of air, gas, carburetted gas and carburretted air under equal pressure through the same aperture (Shilling's test), was: air, 88 secs.; gas, 58 secs.; carburetted gas, 90 secs. corburetted air, 104 secs.

Gas, $\frac{58^2}{88^2} = \cdot434$ to air 1.000.

Carburetted gas, $\frac{90^2}{88^2} = 1.045$ to air 1.000.

Carburetted air, $\frac{104^2}{88^2} = 1.396$ to air 1.000.

Photometric Test.—Test on Hartley's improved photometer, 15-hole argand burner (old standard), 7-in. by 2-in. chimney, consuming 2·04 cubic feet per hour of carburetted gas, = 14·59 standard candles; reduced to the standard of 5·00 cubic feet, = 37·78 standard candles.

Also, with No. 1 steatite batwing, consuming 2·40 cubic feet per hour, = 18·63 standard candles: reduced to the standard of 5·00 cubic feet, = 38·83 standard candles.

3·48 cubic feet per hour of carburetted air consumed through argand burner = 16·52 candles: reduced to the standard of five cubic feet, = 23·70 candles.

Durability Test.—The durability of 1·10 cubic foot 4-inch flame:

	Min.	Sec.
Gas, ...	5	45
Carburetted gas, . . .	16	38
Carburetted air, . . .	11	24

Various forms of machines were experimented on, viz.: cylinders containing lamp cotton, sponge, felt, and wood carbon. They are all useless and obstructive, nor do they yield so high or regular a light as air aspirated or exhausted through gasoline and charged into a gasholder, from which it is supplied ready for use at the burner when required.—*Engineering.*

[Two great objections still exist to the use of these machines, viz., the impossibility of storing large quantities of gasoline without the risk from fire to property in the neighborhood, and secondly, that if the pressure becomes excessive, the flame from the burner will be blown out, and terrible explosions, resulting in loss of life, have followed in consequence. The increase in the illuminating property of coal gas, as ordinarily furnished, when passed through these machines, is very great, and the flame, also, is not liable to be blown out with increased pressure, and a wide field seems to be open in this direction if all danger from fire in the carburetting of the gas could be done away with.]

UNDERGROUND TELEGRAPHING.

Two systems have been proposed, each of which has its advocates. In one, known as the Alberger plan, tubes of glass are prepared of a convenient length and about one-eighth of an inch internal diameter, in which a steel wire is introduced. The compound tube is then inserted in an iron one, which is placed in a furnace and brought to a welding heat, and then passed through a set of rolls, reducing the iron pipe sufficiently to make a solid mass of pipe, glass and coating. This coating of iron not only acts as a protector, but is a shield and an arrestor of the induced currents which are so troublesome in telegraphing on the ordinary lines. The wire being perfectly insulated and protected from all outside influence, is capable of working to a higher capacity, it is claimed, and with less resistance than any other known system. To connect the wires, a trench is dug of any depth desired and a battery attached to the first piece of pipe and tested with a galvanometer, and so with each one, the wire being connected by the ordinary telegraph tie. A sleeve somewhat longer than the pipe, of bell shape, is drawn over each joint when connections are made. This sleeve has an orifice in the centre, into which is poured, in a liquid state, an insulating fluid that fills the entrance of the sleeve, making a joint impervious to moisture and perfectly insulated.

The second system is the invention of David Brooks, the well-known electrician, who has long entertained the belief that a plan of underground telegraphy could be devised which would be far superior, in point of economy and convenience, to the overhead one, despite many experiments in this country and elsewhere to the contrary, the great object being to find something which once placed in a pipe containing wires would prove impenetrable to moisture, water having such effect upon underground lines that a very little would be sufficient to destroy all communication. After trying many substances, he commenced to experiment with oils, and his system consists in placing the wires, wrapped in cotton, twenty, thirty or more in an iron pipe of the proper size, and, after it is laid, oil is introduced and allowed to run its entire length, the source of supply being an elevated vessel always kept full, so as to keep a constant pressure on the oil already there, such pipes having been first laid in Philadelphia. The strong point in the new system is its economy, and it is found in the fact that any number of wires may be enclosed, as has been remarked, in a small space, each one being a separate means of communication, while the work of laying them does not involve much expense. Once in place, they are free from disturbances of all kinds. It is probable, therefore, that no more pole lines will be erected in cities, and our telephone wires over the roofs of houses be done away with.

NEW APPLICATION OF PAPER.

A list of the various useful purposes to which paper or *papier maché* has been applied during the last few years is remarkable by reason of the great diversity which it presents. Besides ornamental articles of almost every form, sundry articles of clothing, bedding, stamps, boxes, barrels, picture-frames, various articles of furniture, stove-pipes, chimney-pots, bricks, partition walls of houses, carriage wheels and boats figure amongst the multitude of appliances to which the inventive ingenuity of manufacturers has succeeded in adapting this single substance, and almost every week some new production is recorded. The last application to which this useful material has been put is the result of a peculiarly ingenius idea. Professor Greene, of the Polytechnic Institute at Troy, has recently had an astronomical observatory erected, the revolving dome of which is to have an internal diameter of twenty-nine feet. A dome of this size, constructed in the usual manner, would have weighed from five to six tons, and would, consequently, have necessitated foundations of considerable depth for its support, but, in addition, would have required powerful and complicated machinery in order to move it. While considering these conditions, the idea struck the astronomer that the substance which had been already put to such multifarious uses could be made to serve his purpose in a satisfactory manner. He therefore applied to a manufacturer of *papier maché*, who, under his direction, constructed a dome which fulfilled in every respect the anticipations that had been formed. In place of the heavy metal framework, such as is usually employed in such structures, a light but firm framing of wood has been erected, and on this the paper. By means of a special preparation, this substance has been rendered fully as hard as the wood and even more rigid than the latter substance. It has been reduced, by subjecting it to enormous pressure, to a thickness of one-sixth of an inch. Thus the total weight of the dome, instead of amounting to some five or six tons, does not exceed a ton and three-quarters; and being mounted on pivots six-eighths of an inch in diameter, working in iron grooves, the whole is capable of being revolved in any direction required without the assistance of any machine or apparatus of any kind. We are not informed what is the difference of cost between such a construction and one answering the same purpose made in the ordinary way, but it is probable that the difference would be considerable, independently of the saving in machinery and of the economy which must result from the employment of a far less solid foundation than would have been necessary in order to support a dome of metal. There is, therefore, every reason to believe that the adoption of this system presents wonderful advantages from numerous points of view. —*L'Ingenieur Universel.*

ELECTRIC LIGHT AT THE BRITISH MUSEUM.

The experimental lighting of the reading-room of the British Museum by means of the electric light has proved a great success. This immense building, which is surmounted by one of the largest domes in the world, was recently illuminated for several evenings by Jablochkoff candles. Fifteen out of nineteen reading-desks with which the room is furnished were lighted by eleven candles, each enclosed in an opalized glass globe and placed on a pedestal fifteen feet high fixed in the centre of the desk, a twelfth lamp being placed in the centre of the room. The effect was very striking, the light being sufficiently bright to enable the smallest print to be read, and writing, tracing, drawing, and even coloring, to be accomplished with ease and comfort at each of the desks. The source of electricity was a 20-light Gramme machine, driven by a Robey portable engine of 16 nominal horse-power. Four circuits of four lamps each were used, twelve being placed in the reading-room, one in the entrance-hall, one in the portico and two in the machine and engine-shed. On this occasion an improved form of the electric candle was used for the first time, in which the kaolin seam or dividing plate is replaced by a composition which is a feeble conductor of electricity.

By this modification the use of carbon priming for lighting and relighting is dispensed with, and the necessity of relighting by hand avoided, and one or several candles may be lighted or extinguished at once by simply turning the handle of a suitable commutator. Moreover, if one of the candles should become extinguished from any accidental cause, it will immediately relight itself without affecting its neighbors in the same circuit. The trial of the electric light under these conditions has given such satisfactory results that it has been decided to extend the application of this system of lighting to other parts of the building, so that hereafter the public will be able to visit the British Museum in the evening—a privilege which has been denied them hitherto, the trustees having been unwilling to expose that magnificent establishment to the risk which is inseparable from gas-lighting.—*L'Ingenieur Universel.*

JAMIN ELECTRIC LIGHT.

The greatest possible simplicity is claimed for it. The two carbons are kept parallel by two insulated copper tubes, separated by an interval of two or three millimetres, in which they slide by friction and which serve at once to direct them and to guide the current. They are surrounded by a directing circuit composed of five or six spirals coiled on a thin rectangular frame, ·40 m. long and ·15 m. broad. This circuit, traversed by the same current as the carbons, and in the same direction, guides and fixes the electric arc at the extremity of the points.

The lighting is effected automatically. For this purpose the two extremities of the carbons are surrounded by a thin rubber band, which keeps them close together. Between them, a little above, a small fragment of iron wire is introduced, which keeps them in close communication by a single point. As soon as the circuit is closed the current traverses this wire, makes it red-hot and melts the rubber; the two carbons thus freed separate, and the arc is established. Carbons of any size may be employed up to 8 mm. diameter. At this limit the waste scarcely exceeds 1·08 m. per hour. The apparatus may be suspended either with the points upwards or directed towards the ground. For several reasons the latter is preferable. With its points downwards, Jamin claims for the light the following advantages: 1. That of simplicity, since it requires no mechanism and no preliminary preparation; all is reduced to a support and to carbons. 2. That of mechanical economy, since it succeeds in almost doubling the number of lights. 3. Increase of illumination, since each of the new lights is nearly twice as powerful as the old. 4. Quality of light, which is more white. 5. A more advantageous arrangement of the poles, which throw their greatest amount of light downwards, where it is required, instead of losing it towards the sky, where it is useless. 6. Economy of the combustible material, since the waste is less in proportion to the size of the carbons.—*Nature.*

Colored Pencils.—L. von Faber makes pencils for writing upon glass, porcelain, metal, etc., as follows—Black: ten parts of lamp black, forty parts white wax, ten parts tallow. White: forty parts white lead, twenty parts wax, ten parts tallow. Blue: ten parts Berlin blue, twenty parts wax, ten parts tallow. Dark blue: fifteen parts Berlin blue, five parts gum arabic, ten parts tallow. Yellow: ten parts chrome yellow, twenty parts wax, ten parts tallow.—*Dingler's Journal.* C.

Astronomical Museum.—Admiral Mouchey proposes to form an astronomical museum in the Paris Observatory. It is to contain: 1. A collection of the portraits of the astronomers and learned men who have distinguished the observatory since its foundation. 2. A collection of medals relative to the history of astronomy and of the observatory. 3. A collection of designs, engravings and photographs representing celestial bodies and astronomical phenomena. Many of these documents, such as Cassini's beautiful collection of drawings of the moon, have been almost forgotten and are now inaccessible to many astronomers who would feel a great interest in consulting them. 4. A collection as complete and methodical as possible of old astronomical and physical instruments, and of everything which can be found in connection with the base of the metric system. 5. Reduced models of instruments which are now in use in foreign observatories, and of special arrangements in those observatories which appear to be useful. —*La Nature.* C.

Estimation of Manganese, especially in its Alloys with Iron.—By F. Kessler.—The author gives details of improvements on a process published by him in the *Zeitschr.*, II., 255 ; the original was available to determine manganese up to thirteen per cent., but as the percentage of manganese may now reach ninety, a modification became requisite.

The solution of iron and manganese as chlorides is slightly over-saturated with sodium carbonate solution (100 grammes of crytals to the litre), and hydrochloric acid (1·01 sp. gr.) is then added until the solution just clears. Both these liquids are best run in gradually from burettes. After diluting, sodium sulphate solution (100 grammes of crystals to the litre) is added to the cold solution in the proportion of 15 c. c. for each gramme of iron ; and the whole, after being made up to a known volume, is filtered uninterruptedly through a dry filter. Mere traces of iron remain in solution and do not interfere with the titration of the manganese. From 50 to 150 c. c. of this filtrate, which must not contain more than 1 decigramme of manganese (as previously determined by the estimation of the iron), are then added to a mixture of 100 c. c. of saturated bromine water with 20 c. c. of sodium acetate solution (500 grammes of crystals to the litre), and 50 c. c. of zinc chloride solution (200 grammes of zinc to the litre). The solution containing manganese should be added in five nearly equal portions at intervals of a quarter of an hour. Then 20 c. c. more of the above sodium acetate solution are added, and the whole boiled until the smell and color of bromine have vanished. The precipitate is then rinsed out into a filter, washed with dilute sodium acetate solution (one-fiftieth the strength given above), and the precipitate and filter returned to the precipitation flask. The object of precipitating the manganese in the presence of zinc chloride is to prevent the formation of lower or higher oxygen compounds of mangenese.

A solution of antimonious chloride (15 grammes of antimonious oxide dissolved in 300 c. c. of hydrochloric acid to the litre) is then added to the precipitate in the flask ; it is added 5 c. c. at a time until, after being well shaken with the precipitate, the latter is no longer black, but brown ; 25 c. c. of hydrochloric acid (·1·19 sp. gr.) are then added, as soon as the precipitate is completely dissolved, the whole is rinsed with 200 c. c. of water into a beaker and titrated with standard permanganate. In this titration the action of antimonious chloride on the permanganate is very rapid, and a color permanent for six seconds indicates the end of the reaction, even though it may subsequently disappear, from the action of the hydrochloric acid on the permanganate. The solution before titration may be green or yellow from the presence of nickel, copper, cobalt or iron; of these cobalt alone makes the determination too high by one-half the amount of cobalt present.

The author recommends the use of carefully prepared pure manganese pyrophosphate for ascertaining the strength of permanganate solution. The salt is prepared by dissolving in water 40 grammes of crystallized manganese sulphate, and 60 grammes of crystallized sodium phosphate; mixing the solutions, adding hydrochloric acid until clear; then excess of ammonia, again clearing with the acid, filtering, diluting to a litre, and precipitating with ammonia. The precipitate is washed by decantation until it no longer gives the chlorine reaction, and then dissolved in dilute nitric acid, with addition of a little sulphurous acid to reduce manganese sesquioxide; ammonia is added in excess, then nitric acid until clear, and finally excess of ammonia, the precipitate being washed to the same extent as before. This precipitate on ignition gives the pyrophosphate, a portion of which is weighed off after having been recently ignited, dissolved in hydrochloric acid, evaporated over the water-bath, and the water-solution of the residue is titrated with permanganate as directed above. The permanganate solution is made by dissolving the purest salt obtainable, letting the solution become perfectly clear by long standing, and then decanting; it remains unchanged for many months in the dark. Only one specimen of steel—East Indian wootz-steel—was found to be free from manganese.—*Jour. Chem. Soc.*

Patinage of Locomotives.—Sig. P. Oppizzi finds that the diminutions of resistance which are not followed by an equal reduction in the motive force produce an acceleration in the rotative movement of the wheels, which cannot be wholly transformed into an acceleration of the locomotive, and therefore causes slipping. He has given some experimental formulæ which, although not so complete as desirable, show the importance of a more careful regard to the relation between the motive force and the adhesion of the wheels. This relation has been too much overlooked by engineers, who have sought to give increased pressure to the steam, and to work it under too great expansion in order to obtain some ideal economical advantage.—*Il Politecnico.* C.

Vessels of Steel.—Before the various recently discovered methods of manufacturing steel at a low cost were put into operation, it was thought that if the price of steel could only be reduced it would drive iron almost out of use. In a certain way this opinion has been confirmed, for steel is now put to services into which it never entered when the expense of its production was higher; but now that the constructor has it at his option to use either iron or steel, the merits of the latter for several classes of work are accepted less freely than they once were. Until within a short time it has been claimed that apart from cost, a steel ship would be in every way superior to an iron vessel, for as the same strength could be obtained with thinner plates and lighter frame, the hull would be more buoyant, while the enduring qualities of steel were known to be greater under ordinary conditions than those of iron, as in the case of rails. But although the change in the latter has been quite universal when the traffic has been sufficient to warrant it, the extra cost being quite balanced by their superior wear, within a year or two practical experiments have been made which prove in shipbuilding at least it would not be an unalloyed improvement. In the first place, it is found that there is a much greater diversity in the tensile strength of different steel plates than of iron ones, and hence the parts of a vessel might vary considerably in this respect. But the most important defect is found in the rapid corrosion of steel in salt water, and few shipbuilders, in receiving steel plates, could tell whether the metal was comparatively pure or not. Of course the thinner the plates the sooner the corrosion would be apparent, and no coating is known that would entirely prevent this, and yet in such collisions as the case of the "Vanguard" with the great German iron-clad, one might well wish for lighter and stronger vessels, such as steel ones would undoubtedly be. In the rapid development of the British navy a feature seems to be the employment of steel in the construction of ships of all sizes. Deck-plating is now made of it in all instances, as well as the ribs and beams. Steel is also making its appearance in the form of armor, iron plates faced with it having been lately adopted in the turrets of the "Inflexible," which the English hope may indeed carry out its name, thereby reducing the thickness of the plates from 18 to 16 inches, which diminishes the weight by many tons; but wonderful as are the English vessels for size and power, in the matter of guns to be used on them the Italians lead, and poor as that nation is, they still have the ambition to build their ships with armor which, like their guns, shall exceed the English nation.

Mance's Heliograph.—Devices for signaling, in many respects similar to the heliograph, have been in use for a very long period of time. We have a record of the employment of polished metal surfaces to flash the rays of the sun, and thus give warnings of one kind or another, which dates back as far as the Persian invasion of Greece. Immediately after the battle of Marathon, the defeated Persians were signaled by some one on the mountains near Athens, by means of reflected rays of the sun upon the polished surface of a shield, that the city would be put into their possession if they came there immediately with their fleet. Fortunately, in this instance, the signaling was seen by both sides, and the ready interpretation of it by the Greeks, and their speedy return to Athens, saved the city from falling into the hands of the enemy. In this case, the signaling must have been carried on over a space of about eighteen miles, and, with the rude appliances used from that time down to a very recent period, this was about as far as the system could be depended upon to work. But the instrument now in use, the Mance heliograph, is a great improvement on the old methods, for not only does it concentrate the sun's rays, but it flashes them with the utmost precision to any required spot, irrespective of the relative location of the sun. It is, moreover, provided with a finger-key, so that flashes may be made of long or short duration, in this way permitting the employment of the Morse telegraphic alphabet. Under favorable conditions, intercourse has been carried on through the medium of two of these instruments over an intermediate distance of nearly one hundred miles; and at several points occupied by the English army in Afghanistan, regular communication is maintained at distances of not less than fifty miles by heliographic signals. The instrument is admirably adapted for war service, as it weighs only about seven pounds, and can, without difficulty, be carried and worked by one man. Of course, in cloudy weather it is wholly useless, and for this reason can never entirely take the place of flags or field telegraphs; yet there are so many days in a year in which it can be used that it will be strange if it is not made use of in various parts of the world, for commercial as well as military purposes. It has already been proposed to establish a systematic telegraphic communication between various islands in the West Indies by the heliographic process; and we venture to think that before long it will be adopted as a means of signaling between vessels when at sea.

Organic Resistance to a Boiling Temperature.—Ch. Chamberland has found a microscopic organism which lives in nearly all liquid solutions of organic matter, provided that they have been previously neutralized by a solution of potash. It produces germs or spores which, when placed in neutral media, resist a boiling temperature for several hours. A temperature of about 115° (239° Fahr.) kills them very rapidly.—*Comptes Rendus.* C.

Distribution of Heat on the Sun's Surface.—Messieurs L. Cruis and J. O. LaCaille have made a series of observations upon the superficial heat of the sun at the imperial observatory of Rio Janeiro. The radiations from the northern hemisphere are more intense than those from the southern in ratios varying from 1·2 to 1·4, the mean radiation of the southern hemisphere being only three-fourths as great as that from the northern. The greatest radiation is only ·56 as great as it would be if there were no atmosphere; the total radiation is only ·22 as great; in other words, there is an atmospheric absorption of ·78. The observations completely confirm the general results which were obtained by Father Secchi, while they present some divergencies in the absolute values of the radiations.—*Comptes Rendus.* C.

Starch-like Granules in Eggs.—In 1866 M. C. d'Areste found some granules in the yolks of eggs which presented many characteristics of starch. Their existence was at first contested, but afterwards admitted, and various attempts were made to account for them. He has lately continued his investigations, and finds that the granules are insoluble in alcohol, ether, or any of the other common solvents of fatty matters. They are colored blue under the influence of any solution of iodine. Sulphuric acid decomposes them; but acetic acid does not affect them. The largest grains swell under the influence of potash or soda, and resume their primitive volume when placed in alcohol. When their form is very regular they act upon polarized light like grains of starch. They may be separated from the yolk by first hardening it in water of 75 or 80° (157 to 176°F.) so that the globules of the yolk are transformed into hexaedral prisms. These globules are first treated by ether, which dissolves the oil and a portion of the fatty matters, and then by absolute alcohol, which removes the rest of the fatty materials and constracts the albuminous substances, producing partial ruptures, from which the starchy globules escape.—*Comptes Rendus.* C.

International Canal.—The project of a canal between the Rhine and the Maas seems likely to be soon carried into execution. The city of Crefeld has already announced its readiness to appropriate 500,000 marks ($125,000) for the purpose, and it is thought that the German and Dutch governments will contribute the residue.—*Fortsch. der Zeit.*

C.

Another New Metal.—The services the spectroscope is capable of rendering to science become more and more evident daily, the latest proof of the fact being the discovery of a new metal called scandium. In some of the mines in Sweden and Norway small quantities of earthy minerals are found called gadolinite and euxenite, composed of oxides of very rare metals. The bulk of the substance is of a rose-color, arising from the presence of erbium, and is called erbine. At first it was supposed to be simply mixed with some earthy substances which rendered it impure, but not long ago M. Marignac discovered the presence of another metallic substance, which he called ytterbine, the oxide of ytterbium. However, great uncertainty existed as to the composition of these bodies, and M. Nilsen undertook a series of experiments on the subject. M. Berthelot, at the last meeting of the Academy of Sciences, gave an account of what had been done so far, the result being the discovery of a new metal, to which M. Nilsen has given the name of scandium, to indicate that it is of Scandinavian origin. Erbine is, as before mentioned, of a brilliant rose-color, while ytterbine is white. But the separation of the two substances can only be effected with extreme difficulty. The earth has to be dissolved in boiling nitric acid, and the ytterbine then precipitated by sulphuric acid; and M. Nilson found that the operation, repeated more than 20 times, did not completely separate the two bodies. When he had obtained a comparatively pure ytterbine he commenced an examination of it, and then he found that it gave absorption bands in the spectrum unknown to any substance previously examined. After repeated trials he became convinced that he was dealing with a metal never before suspected, and he continued his researches. He is unable to say at present what may be the chemical properties of the new body, as the quantity of material at his disposal was insufficient to allow him to isolate the metal. Nor can he decide as yet as to the place the new metal is to take among the older ones, but he considers that its properties differ materially from those of erbium and ytterbium, and that it should rank between tin and thorium, as the atomic weights of these two are 118 and 234, while he calculates that of scandium at from 160 to 180.

Reversal of Motion Without Gears or Belts.—In 1853, MM. Claparade, Roux and Delille attempted to produce opposite revolutions in two parallel arbors by means of a Watts parallelogram, but these experiments were not satisfactory. Charles Bourdon has lately introduced a contrivance which is based upon the two following theorems: 1. If two cranks, of any length and initial position, turn with the same angular velocity, the point which divides the line of variable length, which joins their extremeties at each instant, describes a straight line parallel to the bisectrix of the angle of the two cranks. 2. When the two cranks are equal, the projection of the joining line on the bisectrix preserves a constant length. By means of an ordinary slide, M. Bourdon compels the middle of the system to take a rectilinear movement. Then, by means of two reciprocating Peaucellier cells, or even without the use of cells, if one extremity of the crank is allowed a slight play, two arbors may be easily connected so as to turn in opposite directions and to avoid any dead point.—*Bull. de la Soc. d'Encour.*
C.

Prime Meridian.—The ancient geographers knew nothing west of the Fortunate or Canary Islands. Ptolemy started from that point to estimate longitude, going eastward to the extremity of the countries which were then known. According to his geography, Paris would have had a longitude of about 23½°. In 1682 the French geographers generally estimated the longitude at 20°, but some writers fixed upon 23½°, 22½° and 20½°. England subsequently adopted the meridian of St. Paul, in London, and afterwards Greenwich. France, in 1789, adopted the meridian of Paris. These examples have been followed by Holland, Spain, Portugal, Russia, United States, Chili and Brazil, each country adopting either its own capital or its principal observatory as the zero point of longitude. In order to remedy the confusion arising from these various meridians, M. de Chancourtois proposes to take the meridian of St. Michel, in the Azores, which agrees closely with that of Ptolemy and that of Mercator, and which seems to have other advantages, because it passes entirely through the ocean for one-half of its extent, and on the other half it only cuts the eastern extremity of Asia, thus separating pretty exactly the old and the new worlds. Bouthillier de Beaumont and E. Corlanbert propose an initial meridian ten degrees east of Paris, and that Italy and the United States should cede to the Republic of Science neutral stations for observatories upon that meridian.—*La Nature.* C.

Physical Modifications of Starch.—M. F. Musculus finds that starchy matter may exist both in the colloid and in the crystalloid state. When colloid, it is soluble in water, saccharifiable by diastasic ferments, and diluted in boiling mineral acids, but it easily undergoes modifications which render it insoluble even in boiling water and unaffected by ferments and acids. Iodine gives it a blue color, while it colors the insoluble form red or yellow. In the crystalloid condition it can be obtained under the form of isolated crystals, which are easily dissolved in cold water; these crystals rapidly unite and then become less soluble. The crystalloid starch then undergoes the same modifications as the colloid; it remains, however, always soluble in water at a temperature of 50 or 60° (122 to 140°F.), and saccharifiable by ferments and acids. In isolated crystals it is not colored by iodine; in thin solutions it takes a red color; in concentrated solution a violet or blue color, according to the degree of concentration. It passes through parchment paper, although with difficulty.—*Comptes Rendus.*

C.

Improvements in Coating Mirrors.—The French Academy has awarded a prize of 2500 francs to M. Lenoir for improvements which secure to mirrors all the advantages of silvering, together with the qualities of amalgamation under conditions which preserve workmen from exposure to mercurial vapor. The glass, after being silvered by means of tartaric acid and ammoniacal nitrate of silver, is exposed to the action of a weak solution of double cyanide of mercury and potassium; there is thus formed a white and brilliant silver amalgam which adheres strongly to the glass. The operation is facilitated, and all the materials are economized, by sprinkling the glass at the moment when it is covered by the mercurial solution, with a very fine zinc powder, which precipitates the mercury and regulates the amalgamation. Mirrors which are thus prepared are free from the yellowish tint of ordinary silvered glass, and the amalgam is not easily affected by sulphurous emanations. The committee, in their report, also recount M. Lenoir's improvements in galvano-plastic processes, his discovery of an autographic telegraph, which reproduces writings or drawings with printer's ink, his new and ingenious methods for securing the synchronism of the transmitter and the receiver, and the well-merited reputation which he has acquired from his gas motor.—*Comptes Rendus.*

C.

Pre-historic Flax.—Prof. Heer has found that the flax which was cultivated by the inhabitants of the lake dwellings is of a different species from that which is now raised. It had smaller seeds and sent numerous stalks from the ground, while the variety which is now cultivated has only a single stem.—*Fortsch. der Zeit.* C.

Wear of Materials.—M. Lavoinne commends the St. Louis experiments which are described in the Mayor's message for 1878. Although they are too few to furnish practical results of great value, the principle is good and the mode of experimenting is so easy that it is desirable to use similar apparatus elsewhere for similar researches.—*Ann. des Ponts. et Chauss.* C.

Parchment Cotton.—Imitation woolen fabrics are manufactured in England from cotton which has been subjected to a process similar to the one which is employed in making parchment paper. The cotton is exposed for 24 hours in a mixture of one part of concentrated sulphuric acid, one part glycerine and three parts water, which is kept at a temperature of 17°C. (63·5°F.) The cotton is then pressed between glass rolls and washed until litmus paper shows no trace of acid.—*Indust. Blatt.* C.

Prize to Alexander Agassiz.—The Sevres prize of the French Academy has been awarded to Alexander Agassiz for his numerous and extensive researches in general embryology. The committee, in their report, state that these researches extend over a period of fifteen years, and that the results are noteworthy, not only for their scientific importance, but also for the persevering efforts which have led to them. They display great vigor in the observations, abundant sagacity in the comparisons, dignity and wise reserve in the inductions.—*Comptes Rendus.* C.

Temporary Magnetism of Nickel and Cobalt.—Henri Becquerel has been pursuing an extensive series of experiments upon the temporary magnetism developed in various specimens of nickel and cobalt as compared with that of iron. He finds that when bars of nickel, which are chemically pure, are employed, they give results very similar to those of soft iron. One very remarkable bar of nickel, which was probably porous, appeared to be a little more magnetic than iron. He found very little difference between the nickel and the cobalt. He proposes to follow these experiments by a special investigation of the permanent magnetism of the three metals.—*Comptes Rendus.* C.

New Material for Vases.—The weight and brittleness of terra cotta are great objections to its use in household utensils and ornaments. To avoid these objections, Messrs. David & Co. employ cotton pulp covered with a special composition, which contains a soluble varnish. Articles which are made with this material are very light and very strong.—*La Gaceta Industrial.* C.

African Travels.—Serpa Pinto has traversed the Zambese from the west to the east. The Lisbon Geographical Society has lately received the following despatch from him: "I am within six days of the Indian Ocean, on the eve of terminating my tour across Africa from the west coast. I have striven against hunger and thirst, wild beasts, savages, inundations and drought; I have happily surmounted all these obstacles. Works saved: twenty geographical charts, three volumes of important co-ordinates, meteorological studies, three volumes of drawings, a voluminous journal. I have lost many of my men. Complete study of the upper Zambese; seventy-two cataracts and rapids. Plan of the cataracts. Natives ferocious; constant wars."—*Comptes Rendus.* C.

Ethiopian Honey.—In subterannean cavities, in Ethiopia, a honey is found which is made without wax by an insect resembling a great mosquito; the natives call it *tazma*. M. A. Villiers gives the following analysis:

Water,	25·5
Levulose and glucose,	32·
Mannite,	3·
Dextrine,	27·9
Ash,	2·5
Impurities and loss,	9·1
	100·0

There is a small proportion of a bitter principle which has not been isolated, but which is not nitrogenous. The composition of this honey is similar to that of the mannas of Sinai and Kurdistan, which were formerly analyzed by M. Berthelot, that of the sugary matter in the leaves of the linden, analyzed by M. Boussengault, as well as that of ordinary honey. It differs from all these substances in the absence of cane sugar.—*Comptes Rendus.* C.

Proposed Artesian Well in Madrid.—Proposals have been issued for the speedy boring of an artesian well in the Spanish capital of sufficient capacity to give a minimum supply of 50 litres (11 galls.) of water per second. It is believed that this supply will be reached at a depth of not over 400 metres (437·45 yards). Many of the nobles and capitalists are much interested in the project, and it is thought that a company will soon be organized for carrying it into execution.—*La Gaceta Indust.* C.

Photographic Rifle.—M. Marey having expressed a wish for the invention of a photographic rifle which could take instantaneous views of birds in their flight, Capt. Eugene Vassel proposes a small dark rifle chamber of 35 milimetres (2·27 in.) interior diameter, surmounted by a proper level and sight. By means of Muybridge's, Janssen's or other contrivances for taking instantaneous pictures, he thinks that small views might be easily taken which could be subsequently enlarged. He also proposes a photographic revolver for taking a series of successive attitudes at a single operation.—*La Nature.* C.

Montyon Prize.—The Corliss engine at the French Exposition of 1878 consumed only one kilogramme (2·2 lbs.) of coal per horse-power per hour. A similar engine of 700 horse-power, constructed by M. Farcot, for the drainage at Asnières, consumes only six-tenths as much. M. Tresca, in recommending, on behalf of the committee of the French Academy, that the Montyon prize should be awarded to the inventor of this engine, stated three special advantages which it possessed: a form of construction which establishes a great firmness between the cylinder and the chief arbor, with the least consumption of material; the separation of the orifices of admission and emission, to the great advantage of the permanence of temperature in the steam at its entrance into the cylinder; and a system of distribution commanded by a central platform for the four openings by means of springs and cams, which secure the opening and closing of the orifices. While claiming for Cavé the principle of separation between the orifices and conduits of admission and escape, the committee consider that Corliss' applications of the principle, the precision of action and the economy of his engines entitled him to the Montyon prize of one thousand francs, and the Academy awarded the prize accordingly.—*Comptes Rendus.* C.

Molecular Light.—In continuing his researches upon "the fourth form of matter," Crooks has constructed an apparatus by the aid of which a great heat is produced when the focus of the rays, which are emitted from an aluminium cup, is deviated laterally by means of a magnet upon the walls of the glass tube. By making use of a moderately large hemisphere, and causing the negative focus to fall upon a piece of platinum-foil, the heat is raised to such a degree that the metal melts.—*Comptes Rendus.* C.

Russian Railway Schools.—There are twelve railway schools in Russia. The programmes include religious instruction, the Russian language, geography, history, mathematics, physics, mechanics, the applications of engineering, natural science, telegraphy, book-keeping, drawing, gymnastics and singing. During the past eight years instruction has been given to 4843 pupils, of ages from 13 to 21. The schools are supported by the railway companies, who pay an annual contribution of 35 fr. per kilometre [$11.26 per mile].—*Ann. des Ponts et Chauss.* C.

Poison Mushrooms.—Mr. J. A. Palmer has a paper on poisoning by mushrooms in the *Moniteur Scientifique.* He states that there are three different ways in which mushrooms may act as a poison. First, they may produce the effects of indigestible matter, as when the hard coriaceous species is eaten; and even the edible mushroom may cause a similar result, for when it is decomposing it gives off sulphuretted hydrogen gas in quantity sufficient to induce vomiting. Second, mushrooms may be gelatinous or acrid. Third, a subtle alkaloid, without smell or taste, is contained in some mushrooms, as, for instance, in the group of the Amanitæ, and is called amanitin. No antidote has yet been discovered for this poison, and to it most of the cases of death following the eating of mushrooms is due. It is at first slow in its action, but after the lapse of eight to fifteen hours, the patient experiences stupefaction, nausea and diarrhœa. Delirium follows, and then death. Mushrooms containing amanitin will impart poisonous properties to wholesome varieties, if both happen to be placed in the same vessel. The poison can be absorbed by the pores of the skin. Mr. Palmer carried in his hand some amanitæ wrapped up in paper, and, notwithstanding the protection which the wrapper should have afforded, he was seized with alarming symptoms.

Origin of Springs.—M. Zweifel combats the idea that springs owe their origin to rain water. He shows by the observations at many important stations that the annual evaporation is largely in excess of the annual rainfall, and that the earth, even in the most absorbent soils, is rarely moistened by the heaviest showers to a greater depth than 40 or 50 centimetres (15·75 to 19·69 in.). Air, however, under the pressure of fifteen pounds to the square inch, can penetrate to much greater depths, and if we suppose that the saturation of the subterraneous air varies in the same manner as that of the superficial layers, the condensation of its vapor may account for all subterranean waters. The rapid increase in the amount of precipitation as we approach the earth's surface lends some confirmation to these views.—*Bull. de la Soc. Indust.* C.

Telephones without Diaphragms.—M. Ader reports some experiments confirmatory of the views of Du Moncel upon telephones without diaphragms. He has often observed that the reproduction of words and sounds, which are occasioned by the interruption of currents, can be made with these telephones with a different quality and upon a higher or lower pitch, according to the degree of tension which is given to the iron wire; but if the fundamental sound of the wire is muffled by holding it between the fingers the sounds which are reproduced become dull, a little more feeble, and always in the same tone. He concludes from his experiments that the sounds which are produced by a magnetic nucleus are probably the result of shortenings and lengthenings of the wire, determined by rapid magnetizing and de-magnetizing.—*Comptes Rendus.* C.

Heraud's New Battery.—This is of simple construction and at the same time constant. The liquid used to excite it is a solution of ammonium chloride, and the depolarizing substance employed is mercurous chloride or calomel. In presence of zinc the ammonium chloride gives zinc chloride, ammonia and hydrogen. The hydrogen reduces the mercurous chloride, yielding metallic mercury and hydrochloric acid. This latter, uniting with the ammonia, gives ammonium chloride again. To prevent the formation of zinc oxychloride and its deposition on the zinc, one-tenth of ammonia solution is added to the solution of ammonium chloride. The zinc is suspended in the middle of the liquid, and the carbon, the positive electrode, is enclosed in a canvas bag. After working on a closed circuit for 248 days, the current retained two-thirds of its original strength. C.

Acoustic Figures.—M. C. Decharme concludes his paper upon the acoustic vibrations of liquids by showing their correspondence with those of the Chladni plates. By experimenting upon circular plates alternately with sand and with water, he finds that the diametral, the concentric, and the compound systems are all equally well represented. The position, extent, and form of the different systems of peripheral internodes and the eccentric networks of different orders can be determined numerically beforehand for a plate of given dimensions.—
—*Comptes Rendus.* C.

Adulteration of Tea.—The adulteration of tea is as old as the tea trade itself. In the year 1783 the quantity of counterfeited tea which was imported into England was more than four million pounds, while the entire supply of genuine tea which was brought by the East India Company did not exceed six million pounds. The adulterations are of four kinds: 1, mineral substances for increasing the weight; 2, mineral coloring materials, which are very rare; 3, organic substances for increasing the weight (these generally consist of leaves of cheaper plants); 4, organic coloring matters and astringent substances.
—*Dingler's Journal.* C.

Colored Photographs.—M. Cros prepares three photographic impressions of any object by sifting the light through solutions which will respectively arrest the green rays, the yellow rays, and the violet rays. The impression from which the green has been excluded, if developed under green light, will appear intensely green at points where the original was the greenest, and pale green or black at the green points where the green was mingled with other colors or was entirely absent. By combining the three negatives, and superposing the images by the help of reflecting prisms, he obtains an approximate solution of the fixation of colors by photography.—*La Nature.* C.

Natural Gelatinous Silicate.—During the summer of 1876, in boring a small tunnel, six kilometres (3·73 miles) east of Lausanne, the workmen found a gelatinous substance of a milky whiteness, resembling semi-liquid starch or soft fat. The unctuous feeling and fatty appearance of the substance led them to give it the name of mineral lard. Prof. Renevier has lately analyzed some specimens, which he finds to contain about four parts of silex, one part of alumina, one part of a mixture of lime magnesia and potash, and six parts of water. The elementary proportions are almost precisely the same as those of gmelinite and chabasite, minerals which have hitherto been found only in a crystalline state.—*Bull. de la Soc. Vaud.* C.

Martin's Steering Apparatus.—This seems to be very nearly the principle of the air-brakes on railway trains, and is novel in the substitution of a lever for the wheel and in the means of applying the steam power. This lever slides from side to side on a curved iron frame and is attached below the deck to a long rod, which in turn works a three-way valve. As the lever is moved it turns the valve, admitting steam to cylinders, the rudder chains being attached to the pistons working in these. When the lever is vertical steam is admitted equally to each, and the pressure is of course the same; but as it is moved, a percentage of steam is transferred from one cylinder to the other, either way, and the movement is so simple that a boy can readily regulate the whole apparatus for a large steamer. Under the present system of wheel steering, two, three, or more men, all travelers across the ocean have noticed, pulling at the wheel, especially in rough weather. Capt. Martin's invention proposes to draw the steam power from the ordinary boilers of the vessel, and in practice it is found that the rudder can be moved much quicker than at present, which is a great advantage, especially when there is danger from collision. With such an aid, which bids fair to supplant the old method—although that will be of course at hand in case it must be resorted to from any accident—and electric lights on the vessel, its path across the great ocean will be comparatively as free from danger as the advanced science of the day can possibly make it.

Book Notices.

AN ELEMENTARY COURSE OF GEOMETRICAL DRAWING. By Geo. L. Vose, A.M. Boston: Lee & Sheppard, 1878. Oblong 4to.

The author gives a number of the more important problems in plane and solid geometrical drawing. He recommends a teacher, that the pupil may avoid falling into errors which are so hard to correct later. To those commencing the study of geometrical drawing it will prove a very good collection of carefully chosen examples. A short explanation of the projections of a point and a line, as well as the traces of a plane, in various positions, would have made the book more complete.

P.

ELEMENTS OF PLANE AND SOLID FREEHAND GEOMETRICAL DRAWING AND SOME ELEMENTS OF GEOMETRICAL ORNAMENTAL DESIGN. By S. E. Warren, C. E. New York: J. Wiley & Sons, 1878. 8vo.

Professor Warren's books on descriptive geometry are so well known and so universally acknowledged as standard works that anything coming from his pen will be sure to be of interest. Both pupil and teacher will find many valuable hints in this little book. The method of describing ovals is a most satisfactory one, as it enables the designer to vary the shape of the curve almost at will. It is of particular value, as he rightly says, being a natural curve of intersection and not an arbitrarily assumed series of circular arcs as most commonly used. His remarks on geometrical symbolism are interesting and ingenious, but would scarcely be appreciated by many of those who might study the book to great advantage. P.

SPON'S ENCYCLOPÆDIA OF THE INDUSTRIAL ARTS, MANUFACTURES AND COMMERCIAL PRODUCTS. Nos. 1, 2, 3. (To be completed in 30 parts.) London and New York: E. & F. N. Spon. 8vo.

A new publication of this kind is most desirable, as many new processes have been brought to light which are evidently not to be found in similar works already existing. It is true, many of these have yearly supplements, which are evidently great additions, but after a given period it will be found of the first importance to republish the whole, and to place the novelties where they justly belong. As a general thing a dictionary of arts and manufactures gives but a general idea of the methods adopted, but how frequently the student desires details that are not there to be found, and we are glad to say that such has not been the case with Spon's Industrial Encyclopædia. In part 1st, for example, we notice calculations relating to the draught and supply of air, etc., in the manufacture of sulphuric acid, the importance of which is as great as the temperature, etc.; the steam required, the manner of regulating the same, plans and sections not only of the various apparatus made use of, but also in many cases of the buildings, showing their general arrangement. The subjects have been written by various authors, who seem to have been very well versed in the topics discussed. We are convinced that if this series be finished as commenced, it will be most valuable to those interested in chemical technology.

W.

TABLES OF THE PRINCIPAL SPEEDS OCCURRING IN MECHANICAL ENGINEERING, EXPRESSED IN METRES IN A SECOND. By P. Keerayeff, Chief Mechanic of the Obourhoff Steel Works, St. Petersburg. Translated by Lugius Kern, M. E., St. Petersburg. London and New York: E. & F. N. Spon. 16mo.

This very curious little work gives an indication of what is really a desirable collation of data for mechanical engineers. It is perhaps one-twentieth or so of the current information as to "speeds" needed for general reference; and the information it contains is hidden by imperfect translation, by the use of mètres per second in place of feet and inches per minute, and by acceptance of working speeds as absolute, when limits of speeds much above or far below those quoted are possible. Besides this it can be said that many speeds are given at rates to be considered rather as particular examples than as those of good practice. B.

SUPPLEMENT TO SPON'S DICTIONARY OF ENGINEERING (CIVIL, MECHANICAL, MILITARY AND NAVAL). Parts 1, 2, 3. To be completed in 15 monthly parts.

We have no Engineering Dictionary which is better known and has rendered greater service than the main work to which these three parts and those to come will form a supplement.

Care seems to have been taken, in many cases, to complete subjects heretofore somewhat neglected, not only by the addition of new devices, but also considerations of a technical nature that are of great interest.

We notice particularly in Part I, agricultural implements for hand and steam ploughing, etc., have been wisely selected, also various machines for the binding and reaping combined of a crop of wheat, etc.

In Part II, we take pleasure in noticing that the subject of belts and belting has been treated in a lengthy manner. The examples given, we are glad to see, are mostly American, these being mainly taken from our best authority, and to whom much credit should be given; but we regret to state that the initials of this gentleman's name are not correct, and should be J. H. Cooper and not T. Cooper as quoted, his valuable papers having appeared in the JOURNAL OF THE FRANKLIN INSTITUTE. W.

Franklin Institute.

HALL OF THE INSTITUTE, May 21st, 1879.

The stated meeting was called to order at 8 o'clock P. M., the President, Mr. William P. Tatham, in the chair.

There were present 106 members and 40 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 29 persons were elected members of the Institute, and reported also the following donations to the Library:

Specifications and Drawings of American Patents, for December, 1878. From the Patent Office.

Postal and Commercial Intercourse between the United States and Central and South America, Washington.

From the Postmaster-General, Washington.

Direct export of Iron, Steel, etc., from Philadelphia to Foreign Countries in 1878.

Industries of Philadelphia, as shown by the Manufacturing Census of 1870. By L. Blodget. Philadelphia, 1877. From the author.

Laws of Patents of the United States. 1878.

From the Patent Office.

Notes sur les Paratonneres. Par M. Melsens.

L'Application du Rhé-electrometre aux Paratonneres des Télégraphes. Par M. Melsens.

Notice sur la coup de Fondre de la Gare d' Anvers du 10 Juillet, 1865. Par M. Melsens.

From the author, member of Royale Academy, Belgium.

Papers read before the Pi Eta Scientific Society. 1878–79. Rennselaer Polytechnic Institute, Troy, New York. From the Institute.

Annual Statements of Chief of Bureau of Statistics on the Commerce and Navigation of the United States for Fiscal Year ended June 30th, 1878. Part 2—Foreign Commerce.

Swedenborg's Works in 20 volumes.

From the Am. Swedenborg Print. & Pub. Soc., New York.

Annales des Ponts et Chaussées from 1865 to 1870 inclusive. January to June, 1871; March, 1873; November and December, 1877; January to September, 1878.

Indexes. 1866—1875 in 2 parts.

Etat de l'Eclairage et du Balisage des cotes de France, au 1 er Janvier, 1872. Paris.

Legislation Française des Chemins de fer et de la Télégraphie Electrique. Par M. Cotelle. Second edition. Vols. 1 and 2. Paris.

Annales des Mines. First Series, parts 1–4. Index to Third Series. Fifth Series, parts 1–6; Sixth Series, parts 1–6. Index to Sixth Series.

Rupport sur l' Amelioration Sanitaire et Agricole de la Dombes, 1859.

La Seine. Etudes hydrologiques régime de la pluie, des sources, etc. Par M. Belgrand. Paris, 1872. 2 volumes.

Enquette sur les moyens d' Assurer la Régularité et la sureté de l'Exportation sur les Chemins de fer. Paris, 1858.

Travaux publics des Etats Unis d'Amerique en 1870. Par M. Malézieux. Paris, 1873. 2 volumes.

Question des Houilles. Mission de M. De Ruolz en France et en Angletere. Vols. 1 and 2, text. Vol. 3, statistical atlas. Paris, 1872—1875.

Tramways et Chemins de fer sur routes. Par P. Challot. Paris, 1878. From the Minister of Public Works, France.

Traité des Machines à vapeur. Par Bataille et Julien. Paris, 1847–49. 2 volumes. From Fredk. Graff, Paris.

Annual Reports of the Various Officers and Standing Committees of the City of Allegheny for 1878.
From James Brown, Comptroller.

Betriebs-Einrichtungen auf Amerikanischen Eisenbahnen, etc. Von H. Bartels. Part 1. From W. Lorenz, Philadelphia.

Introduction a l'Atlas des Monuments de la Geographie. Par Feu M. Jomard. Paris, 1879. From the author.

Alamanaque de la Gacetta Industrial para 1879.
From the Gacetta.

Memorial Address upon the Character and Public Services of Morton McMichael. By J. W. Forney. Philadelphia, 1879.
From the author.

The following are from Mrs. E. K. Williams, Delaware Co., Pa.:
Slide Valve Practically Considered. By N. T. Burgh. Philadelphia, 1867.

Rudimentary Treatise on the Drainage of Towns and Buildings. By G. D. Dempsey. London.

Brief Treatise on United States Patents. By H. & C. Howson. Philadelphia.

Treatise on Water Works. By Samuel Hughes. London.

Catechism of the Steam Engine. By John Bourne. New York.

Practical Treatise on Heat. By Thomas Box. Philadelphia.

Ordnance Manual for use of the Officers of the U. S. Army. Second edition. Richmond.

Heat Considered as a Mode of Motion. By John Tyndall. New York.

Appleton's Dictionary of Machines, Mechanics, Engine-work and Engineering, in 2 volumes. New York.

Dictionary of Arts, Manufactures and Mines. By A. Ure. New York. 2 volumes.

Report of the Superintendent of Public Instruction of the Commonwealth of Pennsylvania.

Circuit Court of United States for the Eastern District of Penna. Locomotive Engine Safety Truck Co. *vs.* Pennsylvania R. R. Co. Philadelphia, 1877.

Physical Geography of the Sea. By M. F. Maury. New York and London.

Proceedings of the American Association for the Advancement of Science. Vols. 21—26.

Foundations and Concrete Works. By E. Dobson. London.

Strength of Materials. By William Kent. New York.

Chemical Technology. By Dr. F. Knapp. Vol. 2. Philadelphia.

Proceedings of Twenty-sixth Annual Meeting of Board Supervising Inspectors of Steam Vessels. Washington.

The High-pressure Steam Engine. By Dr. E. Alban. London.

Locomotive Engine, and Philadelphia's share in its Early Improvements. By Joseph Harrison, Jr. Philadelphia.

Manual of Engineering, Specifications and Contracts. By L. M. Haupt. Philadelphia.

Papers on Iron and Steel. By D. Mushet. London.

Reports of the United States Commissioners to the Paris Universal Exposition, 1867. By W. P. Blake. Washington.

Report on the Physiques and Hydraulics of the Mississippi Rivers. By Humphreys & Abbott. Philadelphia.

The following are from the Secretary of the Interior:

Report upon the Yellowstone National Park to the Secretary of the Interior. By P. W. Norris. Washington.

Reports on the Methods of Surveying the Public Domain to the Secretary of the Interior. By J. W. Powell. Washington.

Report on the Geographical and Geological Survey of the Rocky Mountain Region. By J. W. Powell. Washington.

Preliminary Report of the Field Work of the U. S. Geological and Geographical Survey of the Territories. Washington.

Bulletin of the U. S. Geological and Geographical Survey of the Territories. Vol. 4, No. 4. Washington.

Birds of Colorado Valley. By Elliott Coues. Part 1st. Washington, 1878.

Chart of the Geographical and Geological Survey of the Rocky Mountains. J. W. Powell, Geologist in charge.

Report of the Chief of the Bureau of Statistics on Commerce and Navigation, 1878. Part 1—Foreign Commerce.
From the Hon. Charles O'Neill, M. C., Washington.

Reports of the Commissioner of Education for 1870–71. Washington.

Special Report on Education in the District of Columbia. By Henry Barnard. Washington.

Circulars of Information of the Bureau of Education. Nos. 1, 2, and 5 of 1873; No. 2 of 1878, and No. 1 of 1879. Washington.
From the Commissioner of Education.

2d to 15th Reports of the Commissioners of Internal Revenue. Washington.

Reports of the Secretary of the Treasury on the State of the Finances for the year 1858, 1860, 1864, 1866, 1867, 1870–72, and 1874–75.

Reports of the Secretary of the Treasury on Commerce and Navigation of the U. S. for 1852, 1857, 1859 and 1864.
From the Secretary of the Treasury.

Reports of the Commissioners of General Lands for 1871–75 and 1877–78.

Maps of States of Illinois, Iowa, Mississippi, Missouri, Arkansas, Michigan, Indiana, Alabama, Ohio and Wisconsin.

Catalogues of the Publications of the U. S. Geological and Geographical Survey of Territories. F. V. Hayden. Washington.

Bulletin of the U. S. Entomological Commission No. 1. Washington.

Miscellaneous Publications. No. 1—Lists of Elevations. Washington.
From the Secretary of the Interior.

1st to 5th Reports of Major C. B. Comstock upon the Improvements of the South Pass of the Mississippi River. Washington.
From the Chief of Engineers.

Bulletin de la Société Industrielle de Mulhouse. No. 140, 1857; September, 1860; November, 1861; January and March, 1862; August, 1865; July and August, 1872, and January, 1874.
From Mr. Henry Schlumberger, Guebwiller, Alsace, Germany.

Third to Tenth Annual Reports of the Provost of the Peabody Institute of Baltimore.

Discourse on Life and Character of George Peabody. By S. T. Wallis. Baltimore.

Proceedings on the Announcement of the Death of Hon. John P. Kennedy. Baltimore.

Address of the President and Report of the Treasurer and Provost to Trustees of Peabody Institute. Baltimore.

Peabody Institute, Baltimore. The Founders, Letters, etc.

Peabody Institute. Academy of Music and Instructions.

Annual Report of the Board of Commissioners of Public Schools. Baltimore From P. R. Uhler, Librarian Peabody Institute.

Annual Report of Board of Commissioners of Public Schools.
From the Commissioner.

Charter and By-Laws—Commencement Schools of Art and Design and Book-keeping—Maryland Institute.
From the Institute, Baltimore.

Mr. Charles H. Roney made some remarks on Bituminous and Anthracite coals, coke, etc., and the percentage of phosphorus was exhibited by a table thrown upon the screen. He also read a letter of Dr. Charles M. Cresson to W. E. C. Coxe, Esq., relating to the subject.

Mr. Outerbridge explained his method for making diagrams for the lantern in an expeditious way.

The Secretary's report embraced Fleischmann's Improved Switch Faradic Battery; Rappleye's Automatic Governor Burner; Norcross' Furnace Governor; Strohm's Pipe Cleaner; Automatic Fruit Evaporator; Roney's Improved Electrical Pencil; Electrical Clock; Airtight Refuse Can; Sash Opener and Closer, and the Mackinnon Fountain Pen, the iridium ring of which was exhibited with the micromegascope on the screen.

Mr. Bingham explained his pantographic chart for the lantern, which is beautifully colored, and well adapted to give a clear idea of the various geological periods, and the life which existed in those times.

The Secretary read a few remarks on Cowper's Writing Telegraph, Electric Lighting, and Practical Education.

On motion, the meeting adjourned.

Isaac Norris, M.D., *Secretary pro tem.*